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THE UNIVERSITY OF ALBERTA

Long-Term Responses of Subarctic Woodland Vegetation to Human-Induced Disturbance

by

©

Peter David Farrington

A THESIS

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IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF GEOGRAPHY

EDMONTON, ALBERTA

SPRING 1988

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(SIGNED) Peter Farrington

PERMANENT ADDRESS:

10662 65 St.
EDMONTON, Alberta
T6A 2P2

DATED 21 APRIL 1988

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled Long-Term Responses of Subarctic Woodland Vegetation to Human-Induced Disturbance submitted by Peter David Farrington in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE.

G.P. Kershaw.

Supervisor

Edgar L. Jackson

Geo. H. La Roi

Date 13 April 1988

Dedication

This thesis is dedicated to my wife, Wendy. Her constant assistance, love and support made completion of this project possible.

ABSTRACT

Hypotheses of long-term natural revegetation following disturbances in Subarctic Canada range from enhancement to degradation. In light of these postulates, responses of *Picea glauca*-feathermoss vegetation to 40 year CANOL No. 1 Project disturbances were investigated. A section of the CANOL Road, three borrow pits, two bladed slopes, and three bladed trails were studied 40 Km southwest of Norman Wells, N.W.T. at Milepost 40 of the CANOL Project corridor.

Disturbance-induced changes in species composition were minimal, as all plant taxa on the disturbances also occurred in the controls. The major floristic response was a shift in plant growth form and species abundances.

The bladed trails exhibited only minor structural differences from the controls. With the exception of a sparser tree cover, these sites had recovered. Vegetation on the other disturbances had remained, to varying degrees, in a "damaged" condition. This was evidenced by lower species richness, simpler physiognomic structure, and lower plant cover. The road disturbance exhibited the poorest recovery. All perturbed areas contained *Picea glauca* trees, however, thus indicating restoration of woodland vegetation.

Observed plant community responses to the CANOL disturbances were related to perturbation intensity and habitat quality. Generally, recovery was greatest on the low magnitude disturbances, where associated habitat changes were minimal.

Acknowledgement

The author acknowledges Dr. G. P. Kershaw's assistance, as supervisor, throughout this study. Sincere thanks are also extended to Dr. G. H. LaRoi and Dr. E. Jackson. Dr. LaRoi's contribution to my thesis was invaluable. He taught me the rudiments of research design, and provided me with the tools for the analysis and interpretation of ecological data. Dr. Jackson's comments at various stages helped me to focus my thesis, and, with some success, express my ideas more lucidly.

I was very fortunate to have Andre Legris as a research assistant. His calm approach and helpful suggestions made for an enjoyable and fruitful field season. Plant and soil identifications were made by Linda Kershaw (vascular plants), Derek Johnson of the Northern Forestry Centre (non-vascular plants) and Dr. W. Pettapiece of Agriculture Canada (soils). Their help is gratefully acknowledged.

I am especially indebted to my parents for their unfailing love, and for their encouragement, which was always just a phone call away. During production of this thesis, logistical help, moral support, and ideas were also provided by many friends and colleagues. Among them were Dr. Paul Addison, Dr. Doug Maynard, Yash Kalra, John Shuya, Frank Radford, Matt Fairbarns and Dan MacIsaac.

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1. INTRODUCTION

The CANOL NO. 1 Project traverses several Subarctic areas between Norman Wells, N.W.T. and Whitehorse, Yukon. Associated perturbations include road, cleared rights-of-way, and borrow pits. The Project was abandoned in 1945, and there were no post-abandonment reclamation attempts. These disturbances, therefore, provide an excellent opportunity to study the long-term natural responses of Subarctic woodland vegetation to human-induced disturbances.

Since the development of oil and gas reserves at Prudhoe Bay, Alaska in 1968, hydrocarbon exploration activities have become more widespread in the North (Haag 1974). In Alaska the 800 km-long Trans Alaska Pipeline System has been in operation since the late 1970's. Gulf, Imperial Oil Limited and Dome Petroleum have undertaken major exploration and drilling projects in the Beaufort Sea and Mackenzie Delta Region. One of the most extensive hydrocarbon developments in Canada is in the Norman Wells area, where facilities have been expanded. Artificial islands have been built in the Mackenzie River to support wells, and a buried pipeline from Norman Wells to Zama City, Alberta has been constructed.

Although the Norman Wells Project represents an unusually large-scale operation for the Western Canadian Subarctic, all phases of hydrocarbon development have occurred elsewhere throughout this region. These phases include exploration, extraction, refinement and transport. Associated with each one of these activities is some form of ecosystem disturbance. Thousands of kilometers of seismic lines have been produced during exploration in the Subarctic. This has resulted in thousands of hectares of deforested land, disturbed soils and, in permafrost zones, thermokarst subsidence and erosion. The other developmental phases - construction through to the operation of drilling rigs, refineries and roads - have also caused extensive ecosystem disruption.

In Canada, all industrial developments must include an environmental impact assessment. Predictions of project-induced changes to "valued" ecosystem components such as endangered species and habitat, are an essential component of this ecologically-based assessment (Beanlands and Duinker 1983). Unfortunately, knowledge of the ecological consequences of industrial perturbations on Subarctic ecosystems is limited. Perhaps the long-term changes in Subarctic plant communities are least understood, as most predictions are considered to be a "poorly quantified guess" (Van Cleve et al. 1983). Although this situation may be due to a lack of research, the prevalence of two conditions which characterize the Subarctic, exacerbates the problem:

1) Revegetation following severe disturbances, such as those associated with oil development, is slow even on non-permafrost terrain (Mikola 1970, Bliss 1979). For example, re-establishment of a *Picea glauca* tree canopy has been estimated by Bliss (1979) to require 200 years, approximately 100 years longer than for the more temperate closed-canopy Boreal Forest (Gill 1973a and 1973b, Bliss 1979, Larsen 1980).

2) Subarctic plant communities on non- or deep permafrost sites appear to exhibit a relatively wide range of responses to similar disturbances. Predictions of long-term revegetation have ranged from restoration or recovery (Mikola 1970, Viereck 1975) to the development of physiognomic and floristic characteristics which differ substantially from the pre-disturbance vegetation (Gill 1973b, Strang 1973). Gill (1973b) hypothesized that the production of a more severe post-disturbance microclimate (colder and drier air and soils), associated with clearcutting, may result in the conversion of Subarctic open-woodland to a physiognomically simpler treeless tundra plant community. Other researchers working with fire and seismic line construction disturbances have described warmer and more mesic soils (Strang 1973, Pettapiece and Zoltai 1974, De Byle 1976). Strang (1973) predicted that these more amenable post-disturbance growth conditions would increase tree productivity and rates of tree regeneration. These two hypotheses represent examples of post-disturbance Subarctic plant community "degradation" and "enhancement", respectively. Others have contended that the creation of enhanced or degraded vegetation is not permanent (Mikola 1970, Viereck 1975). They predicted that floristic and physiognomic differences among pre- and post-disturbance plant communities will abate with time (Mikola 1970). This abatement period may last from decades to several hundred years (Wein and El-Bayoumi 1983).

Two sets of factors form the basis for all of these theories:

1) The responses of Subarctic plant communities are primarily determined by abiotic characteristics of the post-disturbance environment (Mikola 1970, Gill 1973a and b, Strang 1973, Bliss 1979, Van Cleve et al. 1983). Soil temperature is the habitat factor considered to be the most important in this regard (Haag 1974, Van Cleve and Yarie 1986). Soil moisture and chemistry are two other important growth condition factors which mediate ecosystem development (Van Cleve et al. 1983). For example, these three factors regulate nutrient turnover and influence plant production rates, seed germination and establishment success.

2) Both the post-disturbance growth conditions and the recovery period are dependent upon the nature of the perturbation (Bell et al. 1974, Haag 1974, Peterman 1980, Vitousek and White 1981). For example, soil temperature and moisture regimes are markedly different from the pre-disturbed environment if a perturbation has been of sufficient magnitude to reach the duff layer (Haag 1974, Sellers 1974); diurnal and annual ranges in soil temperature are usually greater and soil moisture conditions drier (Zasada 1986). A less severe disturbance, in which the LFH horizon is preserved, would result in fewer habitat changes.

If these changes produce a more amenable habitat then, as Strang (1973) predicted, an enhanced plant community may develop. If, on the other hand, a perturbation generated a less favourable microclimate for plant growth, a degraded plant community may occur (Gill 1973b).

As well as controlling species composition, species abundances and physiognomy, disturbances influence the revegetation response period. Generally, the time required for plant community recovery tends to increase with perturbation magnitude (Kormakova and Webber 1980, Wein and El-Bayoumi 1983).

Other disturbance variables which may affect the flora and/or physiognomy of a plant community, and which are relevant to this thesis, are area, perimeter to area ratio, and the sensitivity of the terrain to perturbation (Kurfurst 1973, Bell et al. 1974, Nyland 1977, White 1979, Peterman 1980, Van Cleve et al. 1983).

Purpose:

The purpose of this thesis is to determine whether disturbances associated with the CANOL No. 1 Project have resulted in long-term (40 years) alterations to *Picea glauca*-dominated Subarctic plant communities. This thesis will also attempt to determine which characteristics of both the initial disturbance and abiotic environment have influenced the observed vegetation responses. To accomplish this purpose three objectives must be satisfied:

1) Measure the long-term (40 years) floristic responses of *Picea glauca*-dominated plant communities to disturbances associated with road, telephone and other rights-of-way construction. Floristic measures will encompass species composition and abundance, and physiognomic structure.

2) Quantify disturbance regime and abiotic variables. The disturbance variables are area, perimeter to area ratio, terrain sensitivity, intensity and severity. Soil moisture, soil temperature, surface pH, and the % organic matter of the surface horizon are the abiotic descriptors.

3) Evaluate the relationships among the floristic, disturbance and abiotic variables.

2. STUDY AREA

2.1 Location

Field research on the CANOL disturbances was conducted approximately 65 km south-southwest of Norman Wells, Northwest Territories (mile post 40). The Dodo Valley (64 °51' N, 127 °14' W , elevation 575 m asl), situated within the Mackenzie Mountains, is an unglaciated river valley approximately 1/2 km wide at the site of the study. CANOL disturbance types located here include several borrow pits, the roadbed and bladed trails (Figure 2.1). Vegetation in this area is classified as Subarctic Forest (Rowe 1972). The site falls within the zone of widespread discontinuous permafrost (Mackenzie River Basin Study Report 1981). The climate is characterized by short, cool summers (average May to September temperatures are 11 °C, with July temperatures averaging 16.2 °C), cold winters (mean October to April temperatures is -18 °C) and low mean annual precipitation (approximately 275 mm) (Crowe 1970, Canadian Climate Program 1982). Geologically, this area consists largely of calcareous Cambrian material (Anonymous 1958). Eutric Brunisols and Regosols are the dominant soil types (CSSC 1977).

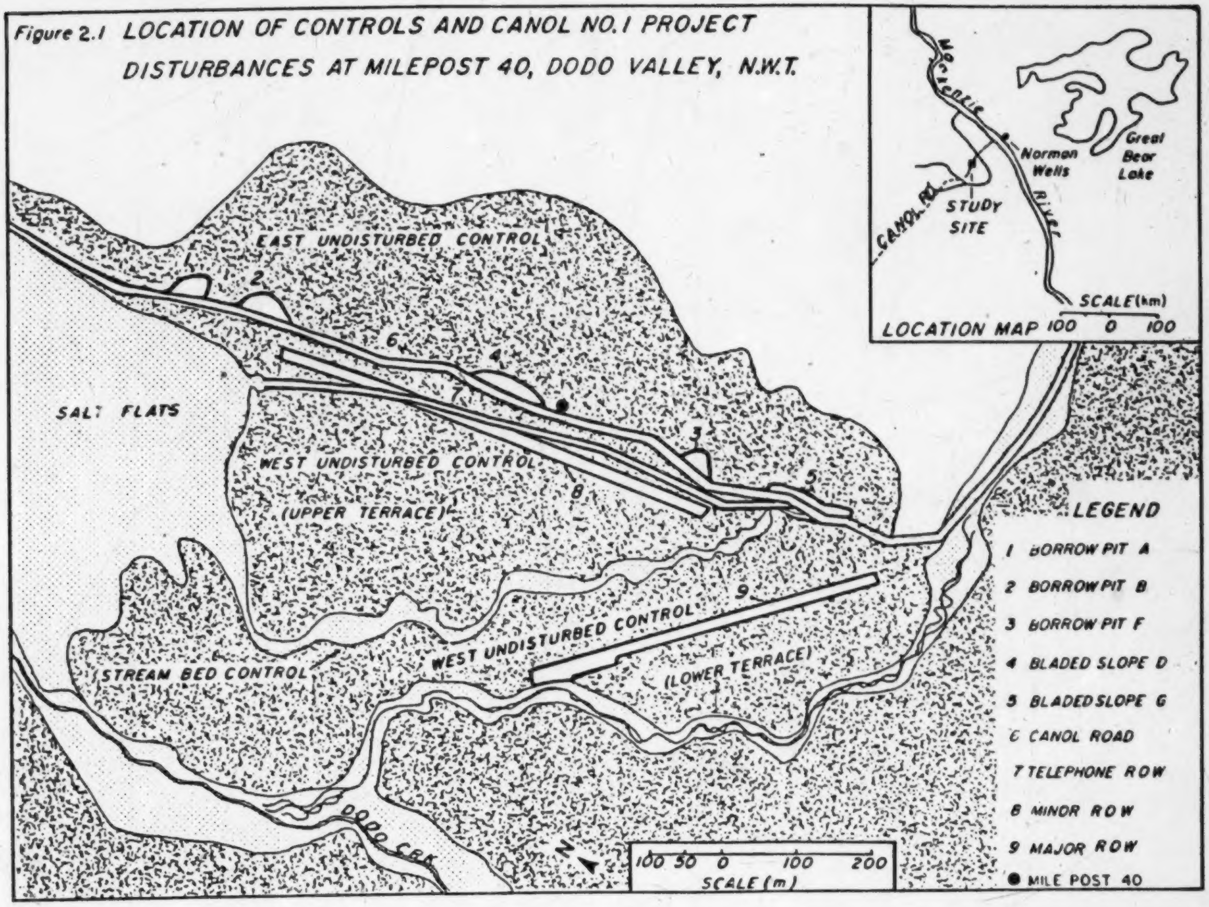
2.2 Geology

Dodo Valley is situated in the Mackenzie Fold Belt of the Cordilleran Orogeny Geologic Province (Fremlin 1974). It lies within the Carcajou Ranges which are directly east of the Canyon Ranges (Aitken and Cook 1974).

The Dodo Valley proper is characterized by surficial deposits of calcareous alluvium, presumably of Quaternary and Modern age (Aitken and Cook 1974). It also contains bedrock material eroded from the surrounding Carcajou Ranges by fluvial, hillwash and landslide activities (Anonymous 1958).

The MacDougall Anticline forms the range east of the Dodo Valley. Four Formations dominate the surficial geology of the section of the MacDougall Anticline, which lies directly east of the study site.

Figure 2.1 LOCATION OF CONTROLS AND CANOL NO. 1 PROJECT DISTURBANCES AT MILEPOST 40, DODO VALLEY, N.W.T.


LOCATION MAP
SCALE (km)
100 0 100
Mackenzie River
Norman Wells
Great Bear Lake
STUDY SITE
CANOL RD.
EAST UNDISTURBED CONTROL
WEST UNDISTURBED CONTROL
(UPPER TERRACE)
WEST UNDISTURBED CONTROL
(LOWER TERRACE)
STREAM BED CONTROL
SALT FLATS
DODO CRK
N
1
2
3
4
5
6
7
8
9
SCALE (m)
100 50 0 100 200
LEGEND
1 BORROW PIT A
2 BORROW PIT B
3 BORROW PIT F
4 BLADED SLOPE D
5 BLADED SLOPE G
6 CANOL ROAD
7 TELEPHONE ROW
8 MINOR ROW
9 MAJOR ROW
● MILE POST 40

They are:

1) the Saline River Formation, which dates to the Upper Cambrian. This Formation is characterized by thin-bedded dolomitic limestones of marine origin, shales, sandstones and siltstones;

2) the Mount Cap Formation. It dates to the Lower and Middle Cambrian and is composed of shale, thin-bedded limestone, sandstone, siltstone and marine material;

3) an unnamed shale-limestone unit originating during the Proterozoic. Shales and dolomite limestone make up this unit;

4) the Upper and Lower Divisions of the Katherine Group, also of Proterozoic Age. The Upper Division is comprised of quartzite, dolomites and shales, whereas the Lower Division is dominated by quartzite with minor shale and dolomite components (Aitken and Cook 1974).

The Upper Cambrian and Lower Ordovician Franklin Mountain Formation dominate the surficial geology of the mountains immediately west of the study site. It is a thick, poorly fossiliferous sequence of carbonate layers (Aitken and Cook 1974). This formation is subdivided into 4 informal members on the basis of lithology and colour. These members are discontinuously distributed within any given stratigraphic section, and may, in some areas, be unrecognizable. The Cherty Member is comprised of dolomite, chert and dusty quartz. The Rhythmic Member contains from very fine to medium crystalline dolomite and marine material. Dolomite, conglomeratic, stromatolitic, argillaceous, and shaly material as well as some marine deposits compose the Cyclic Member, while the "Basal Red Beds" are basically sandstone, red shales, conglomerate dolomite, chert as well as marine and non-marine material.

2.3 Glacial History

Dodo Valley is situated within Rutter's (1984) "Zone of Limited Glacial Activity". This valley was, in all probability, within the boundaries of an ice-free corridor for the entire Wisconsin Era (75,000 to 10,000 BP). Its eastern boundary was the Keewatin sector of the

Laurentide Ice sheet with many, often discrete alpine glaciers lying to the west (Prest 1984). Westward expansion of the Laurentide Ice Sheet into Dodo Valley was probably blocked by the MacDougal Anticline and the Carcajou Range which includes Dodo, Sheep and Sugarloaf Mountains which reach elevations of almost 1370 m. Instead, the ice sheet was directed northward down the Mackenzie Valley towards the Beaufort Sea, and south and southeast, tending to follow the regional topographic trend (Rutter 1984).

Geomorphological evidence supports the view that Dodo Valley was unglaciated during the Wisconsin. Convex slopes are mantled with felsenmere and grus deposits while tors and scree slopes are extensive along the valley sides and within smaller tributary valleys. Many of these same valleys are v-shaped as well, with numerous interdigitating spurs.

2.4 Topography

Dodo Valley, with its high vertical walls and canyons, was cut along the hinge plane of a monoclinal, synclinal bend (Aitken and Cook 1974) and this, combined with the antiquity of these surfaces, probably accounts for the depth to which the valley has been cut. Another possibility is that the valley was incised by meltwater originating with the melting of Early and Mid-Pleistocene-aged glaciers wasting in the mountains west of Dodo Creek.

The moderately-sloped and well-rounded mountains which surround the study area are mantled by a veneer of geomorphologically active scree slopes, talus deposits, solifluction lobes, sorted circles, block fields and block slopes. The morphology south of the study site is characterized by castellated tors which rise above the steep scree slopes. At the base of this tor-scree slope complex is a rocky-bottomed lake. This lake drains into the Dodo Creek which dissects the river valley floor. The valley bottom (elevation 575 m) itself has a low gradient and is 1.5 km long and attains a maximum width of approximately 450 m. Occasional small (1m deep) creek terraces impose relatively minor topographical fluctuations on an otherwise flat valley bottom surface.

While the structural grain of the mountains is from northwest to southeast, the main portion of the Dodo Valley is oriented in a north-south direction. Maximum elevations of mountains abutting Dodo Valley range from 900 - 1122 m asl.

2.5 Drainage

The valley is drained by Dodo Creek, a tributary of the Carcajou River. The Carcajou drains into the Mackenzie River Basin 15 km from the mouth of Dodo Creek. Mountainous topography combined with little or no vegetation cover has produced numerous gully-rivulet systems that feed into the Dodo Creek. As a consequence, infrequent (two episodes observed in a 90 day period) but heavy rainshowers (approximatley 1.5 cm/24 hr period) may produce relatively rapid and large increases in Dodo Creek discharge and turbidity. Flow within intermittent tributary creek beds has also occurred. In addition, a lake at the base of a tor-scree slope complex drains northward into the creek during the ice-melt and ice-free periods. The contribution of this water source would probably be at its maximum during spring-melt. The lake's surface area decreased by 30% over a period from mid-June to July 7/1983. Cold water springs in the Salt Flats, the main valley area, appear to contribute little water volume to the creek, although they do produce a decidedly salty taste to the surface water downstream.

2.6 Climate

Temperature is considered to be a major factor controlling plant productivity in the Subarctic (Mikola 1970). The growing season, which is limited to 3 to 4 months, is beset by frequent killing frosts (Bluthgen 1970), and the 100 ^{o}C range between winter and summer temperatures is larger than for any other global environment (Bluthgen 1970, Crowe 1970, Mackenzie River Basin Committee 1981). The growing season occurs between late May and early to mid-September (Burns 1973). A negative heat balance exists for the rest of the year; insolation is restricted to diffuse light, cold arctic highs are the dominant air masses, and the high albedos (80 to 90% of the visible light spectrum) of snow and ice reflect much of what little radiation input there is during winter (Rouse 1978, Mackenzie River Basin Committee 1981).

Much of the annual precipitation in the Subarctic falls as rain during the summer, when cyclones of warm, humid air create unstable, showery weather (Bird 1972).

Mountainous regions are usually subjected to more precipitation than surrounding plains areas. Orographic rainfall caused by the forced ascent of air masses and their subsequent cooling, is the main reason for the increase (Strahler 1969). This form of rainfall tends to decrease in intensity, both with latitude and altitude, however. Due to its geographic location - a comparatively high latitude and elevation, and a location within the eastern ranges of the most inland mountain chain (the Mackenzies) of the Western Canadian Subarctic - this form of rainfall probably contributes relatively little additional precipitation to Dodo Valley. Localized convectional rainfall was periodically observed in Dodo and other valleys of the Carcajou Ranges. This moisture source may be more important during the growing season than orographic rainfall. Winter precipitation is generally light (Crowe 1970) because of the low absolute humidities created by cold temperatures (Sellers 1974). Although average annual precipitation may be as low as 20 cm (Gill 1974), the climate is considered effectively moist since there is little evapotranspiration (Bluthgen 1970).

No record of climate exists for Dodo Valley. Norman Wells (65 °17' N and 126 °48'W at an elevation of 64 m) and Fort Norman (64 °57' N and 125 °00' W at an elevation of 81 m) are the closest stations which have a long-term record of precipitation and temperature (1943-1980 and 1931-1980 respectively) (Figure 2.2 and 2.3). The more level topography and lower elevations inevitably have produced climates that differ from that of Dodo Valley. For example, Burns (1973) estimated that in the vicinity of the study site precipitation would be greater (approximately 10-20%) and mean annual temperature 2°cooler than in Norman Wells and Fort Norman.

In general, the climate of Dodo Valley is typically Subarctic: the growing season is relatively cool and moist, while the winters are long and cold. Based on available regional climatic data (Figures 2.2 and 2.3), the growing season temperature would be about 11°C, although the mean July temperature may exceed 16°C. Extreme minimum temperatures for the Norman Wells and Fort Norman climatic stations indicate that no month has been

Figure 2.2: Norman Wells, N.W.T.

Temperature and Precipitation Characteristics

(Adapted From: R.B. Crowe 1970, Canadian Climate Program 1982)

Mean Annual Temperature: -6.3°C

Mean Annual Precipitation: 327.7mm

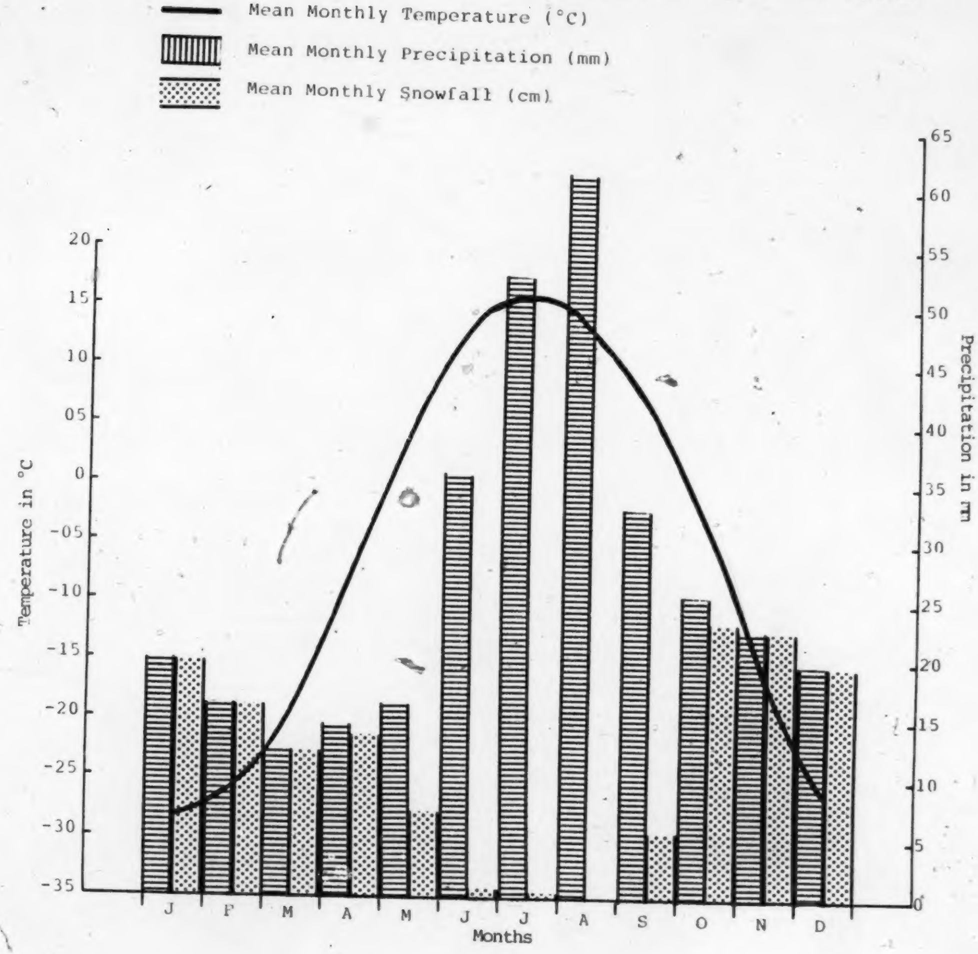


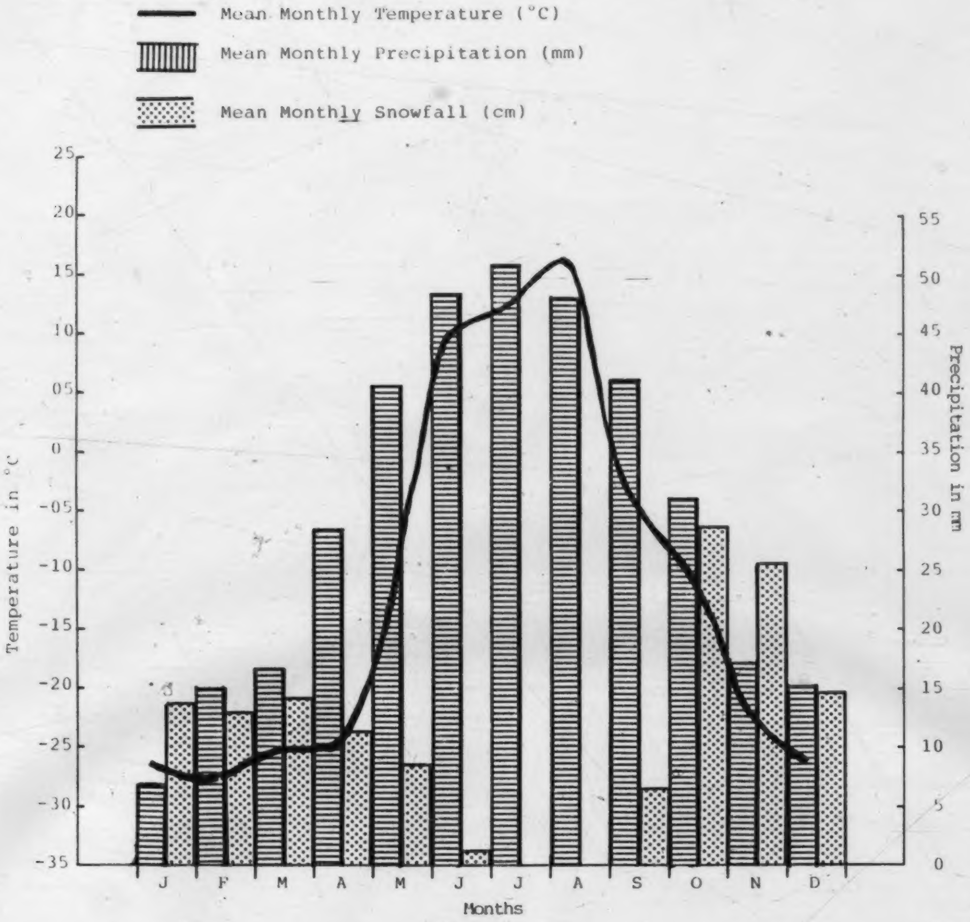
Figure 2.3: Fort Norman, N.W.T.

Temperature and Precipitation Characteristics

(Adapted From: R.B. Crowe 1970, Canadian Climate Program 1982)

Mean Annual Temperature: -6.3°C

Mean Annual Precipitation: 277.4mm



frost-free since records began in 1931.

Total annual precipitation at the two climatic stations is less than 350mm (Figures 2.2 and 2.3). Greater than 60% of this total falls as rain during the May to September period. Although evapotranspiration is relatively low, well- to excessively-drained sites and windswept areas may still experience moisture deficits.

2.7 Soils

Subarctic soils are not as well developed as those in more temperate areas such as the Boreal Forest. For example, Pawluk and Brewer (1975) noted a northward decrease in most pedogenic processes, including podzolization. In comparison to the Boreal region, most soil forming processes are weakly expressed (Pettapiece 1974). As a result a northward increase in Brunisol and cryosol development is associated with a decline in Podsol production (Pettapiece and Zoltai 1974). All soils at the study site developed from calcareous parent material. Consequently, the pH in the upper mineral horizon is neutral to alkaline. This condition would favour the establishment of calciphyte plant species, which are adapted to these calcareous conditions. Three major soil groups were found in the study area. They were Brunisols, Gleysols and Regosols.

Brunisols are imperfectly- to well-drained mineral soils which have developed under the influence of varying types of forest, alpine or tundra vegetation. The processes of leaching and weathering are weakly expressed in Brunisolic soils, and the resultant lack of significant illuviation in the B horizon differentiates this soil group from the Podzols and Luvisols (CSSC 1977). Eutric Brunisols, the only great group in the study area, were largely confined to the scree slope plant communities. They were moderately to excessively stony and well-drained.

Gleysols are poorly-drained mineral soils, which have profiles that reflect the influence of water-logging for significant periods. Both Gleysol sub-groups, the Gleysols and Humic-Gleysols were present, and situated on the elevated alluvial terrace in the study area. Gleysols have no Ah or a thin or weakly developed Ah horizon, whereas the Humic Gleysols have well-developed Ah Horizons overlying gleyed B or C Horizons.

Regosols are well- to imperfectly-drained mineral soils with profile development too weakly expressed to meet the requirements for classification in any other group (CSSC 1977). They lack expression of a B Horizon, but may have a thin organic surface layer. There are two sub-Groups: the Cumulic Regosols and the Orthic Regosols. The former have buried Ah horizons separated by alluvium. These occurred on the lowest alluvial terrace, which supported a pure stand of white spruce. Orthic Regosols have no or thin organic layers with no B Horizon. These soils were restricted to some disturbed sites and scree slopes. Near-surface (< 1m) permafrost was not encountered in the study area. The influence of thermokarst on post-disturbance recovery was, therefore, considered to be minimal.

2.8 Vegetation

The study area is located within the "Forest and Barren" region of the Boreal Forest (Hosie 1979). This corresponds with Rowe's (1972) Subarctic Open-Canopied Woodland. The principal tree species are *Picea glauca* (white spruce), *Picea mariana* (black spruce), *Larix laricina* (larch), *Populus tremuloides* (trembling aspen) and *Populus balsamifera* (balsam poplar) (Porsild 1945, Hosie 1979).

Subarctic forests are characterized by low density stands of relatively low height and slow rates of growth. For example, Whittaker (1975) estimated that productivity in woodlands range from 25,000-120,000 kg $ha^{-2}yr^{-1}$ to 40,000-200,000 kg $ha^{-2}yr^{-1}$ for the Boreal Forest. Moore and Verspoor (1973) reported that biomass values for black spruce stands in Northern Quebec ranged from 10,000 to 29,000 kg ha^{-1} in open-canopy woodlands and from 78,000 to 163,000 kg ha^{-1} in closed-canopy forests. Trees in Subarctic stands were reported to be up to 30% shorter for similarly aged Boreal Forest plant communities (Viereck et al. 1983).

Common understory taxa include *Ledum groenlandicum* , *Vaccinium uliginosum, Dryas integrifolia, Betula glandulosa* and *Salix* spp. Feathermosses such as *Hylocomium splendens* and *Pleurozium schreberi* as well as the reindeer lichen, *Cladina mitis* are abundant non-vascular plant species.

2.9 Disturbance Types

Four CANOL No. 1 Project disturbance types were investigated (Figure 2.1):

1) Road

2) Borrow Pits

3) Bladed Slopes

4) Bladed Trails.

Road

The Road ran in a north-northwest to south-southeast direction through the study area (Plate 1). It had a low grade (1^{o} slope), and was composed of aggregate material removed from borrow pits. The original surface at the south end of the study site was excavated and levelled, and then covered by a relatively thin layer of gravel (as little as 15 cm thick). In contrast, construction of the road at the north end appeared to have entailed removal of above-ground vegetation followed by burial under a relatively thick layer of gravel (thickness undetermined).

Borrow Pits

The three borrow pits had level floors surrounded by steep slopes, and were classified as Side Hill Types. While the floors were compacted, the walls were composed of unconsolidated gravel (Plates 2 to 4). All three pits were subjected to rafting of plant and soil material from the upslope "undisturbed" terrain. This large-scale slumping appeared to be an important factor in the natural revegetation of these pits.

Bladed Slopes

There were two bladed slopes located east of the road on the East Control talus slope (Plates 5 and 6).

The larger of the two disturbances appeared to be a borrow pit, which was probably abandoned during the initial stages of development. It was semi-circular in shape with the

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Plate 2.1 Road

This disturbance bisected the East and West Undisturbed Controls. Note the abundance of Dryas drummondii in the road centre and tall shrubs and trees on the road shoulders.

July 25, 1983

Plate 2.2 Borrow Pit A
This disturbance was located in the East Talus Control. Note the level floor, sods on the unconsolidated walls, and the sparse tree cover.
July 24, 1983

Plate 2.3 Borrow Pit B
This disturbance was located in the East Talus Control. Slope instability is evidenced by the presence of sods and clumps on the side walls.
July 24, 1983

Plate 2.4 Borrow Pit F
This disturbance was located in the East Talus Control. Note the shrub clumps and sparse tree layers.
July 24, 1983

Plate 2.5 Bladed Slope D
This Disturbance was located on the East Talus Control. Note the sparse plant cover and the absence of trees and sods.
July 24, 1983

Plate 2.6 Bladed Slope G

This disturbance was located in the East Talus Control. Note the sparse plant cover and the absence of trees and sods.

July 25, 1983

straight axis parallel and adjacent to the road. This surface had a well-defined border, and there were no traces of the pre-disturbance LFH soil horizon. All woody species post-dated 1942, indicating that the disturbance was of sufficient intensity to have destroyed all above- and below-ground woody plant parts. Although there was no evidence of large-scale slumping from above the bladed slope, as was the case for the borrow pits (indicated by the woody plant ages, and the absence of turf), translocation of organic material downslope from the adjacent upslope undisturbed area was observed during rainy periods. The spatial dimensions of this surface may be gradually increasing in an upslope direction as the organic mat is undercut by erosional processes.

The second and smaller bladed slope was located at the south end of the road on the East Control (Figure 2.1). It was linear in shape and paralleled the road. The origin of this five m-wide perturbation was unclear, but may have been accidentaly produced as a result of a bulldozer unintentionally scraping away the vegetation and organic mat as it graded the road.

Bladed Trails

There were three bladed trails:

1. Telephone Right-of-Way;
2. Minor Right-of-Way;
3. Major Right-of-Way.

The first two bladed trails were situated west of the Road, with the Telephone Line intersecting the Road surface at the extreme south end. The Minor Right-of-Way ended before reaching the Road. Both rights-of-way traversed a mixed white spruce-black spruce-feathermoss woodland whose tree ages exceeded 400 yr. The Major Right-of-Way was located on a lower and, therefore, younger alluvial terrace west of the Road. Vegetation was classified as white spruce - feathermoss woodland with tree ages exceeding 380 yr.

Plate 2.7 Telephone Right-of-Way
This disturbance was located on the West Terrace Control (upper terrace). Note the Picea glauca regeneration and the well-developed shrub layers.
July 29, 1983

Plate 2.8 Minor Right-of-Way
This disturbance was located on the West Terrace Control (upper terrace). Note the tree regeneration and exposed mineral soil.
July 28, 1983

Plate 2.9 Major Right-of-Way
This disturbance was located in the West
Terrace Control (lower terrace). Note
the absence of trees.
August 4, 1983

Telephone Right-of-Way

The north-south oriented Telephone Right-of-Way contained telephone poles, few of which remain standing (Plate 7). It was the longest and widest of the three bladed trails in the study area, attaining a length of 665 m. It averaged 8.8 m in width.

Minor Right-of-Way

The Minor Right-of-Way occurred at a slight angle to the Telephone Line, and crossed it approximately 300 m from the north end of the study site (Plate 8). It averaged 5.5 m in width and was 530 m long.

Major Right-of-Way

The Major Right-of-Way, designated as such because it was 0.5 m wider on average than the Minor Right-of-Way, ran in a north-northwest to south-southeast direction, and was 425 m long and 6.0 m wide (Plate 9). It intersected a washed-out portion of the road, approximately 100 m to the south end of the road surface. This bladed trail traversed a white spruce stand, situated on a lower alluvial terrace, west of the Road.

3. METHODS

3.1 Site Selection

The Dodo Valley site, selected with the aid of aerial photographs (1:13,800, 1944 and 1:12,000 1974) and air reconnaissance, was chosen because of its uniform vegetation and the relatively large number of disturbance types within close proximity.

The control vegetation consisted of riparian spruce-feathermoss and upland white spruce-feathermoss classes, while disturbance types included road, borrow pit and bladed trails. One additional disturbance type, termed Bladed Slopes, was observed in Dodo Valley. These disturbances were irregular in shape, shallow (up to 10 cm below soil surface), and had slopes comparable with that of the surrounding terrain (14^{o} to 17^{o}) (Section 2.9).

3.2 Field Methods

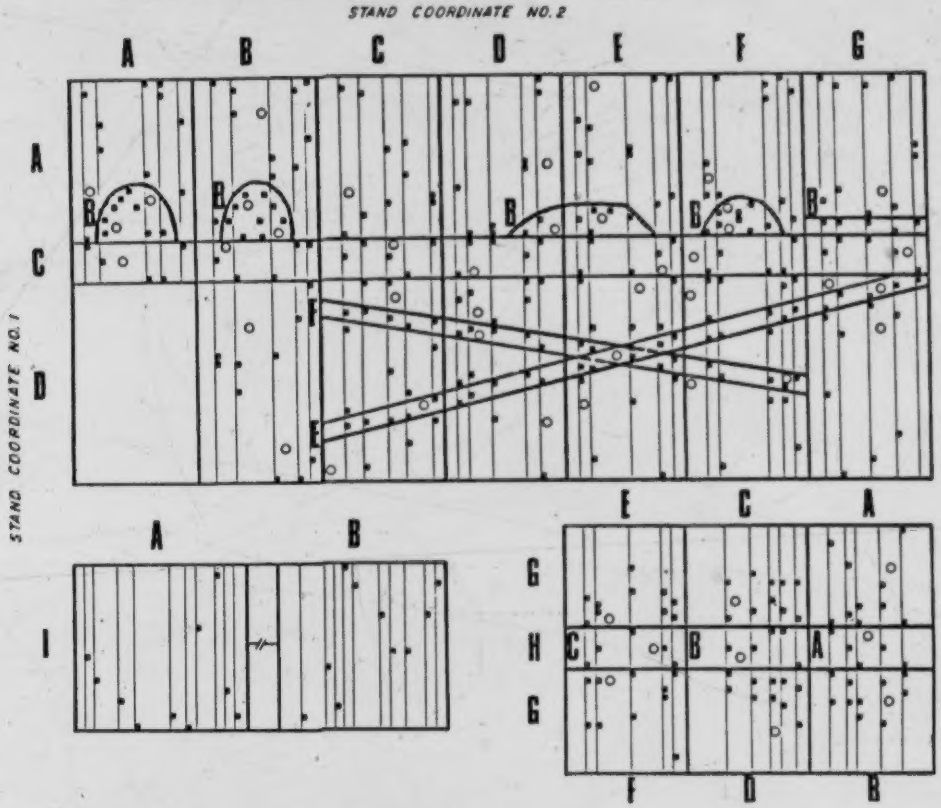
3.2.1 Transect Line Location

A preliminary survey of the southeast portion of Dodo Valley was conducted to locate, identify and delineate perturbations associated with the CANOL No. 1 Project, and to describe and map the adjacent control vegetation into sample areas of relative physiognomic and floristic homogeneity (Figure 3.1).

The control vegetation and all disturbances which exceeded 200m in length, i.e. the three bladed trails and road, were stratified to ensure an even distribution of sample plots (Figure 3.1) (Gauch 1982). Each control stratum or stand was 50m wide by 100m long. Stands located on the linear disturbances were also 100m long, while the breadth was determined by the width of the perturbation. The three borrow pits and two bladed slopes were not stratified, thus each represented one stand.

A total of twenty-one control stands were produced. Thirteen bordered on to the road, six on to the Major Right-of-Way, and two more were located in an intermittent stream bed (Figure 3.1 and Table 3.1). There were twenty-four disturbance stands. The

Figure 3.1: *LOCATION OF TRANSECT LINES(\), QUADRATS(•) AND SOIL PITS(o) ON CONTROLS AND DISTURBANCES, MILEPOST 40, DODO VALLEY, N.W.T. (not to scale)*


STAND COORDINATE NO. 2
A
B
C
D
E
F
G
A
C
D
B
B
B
B
B
F
E
STAND COORDINATE NO. 1
A
B
I
E
C
A
G
H
G
C
B
A
F
D
B

LEGEND

AA-AG	East Control	EC-EG	Telephone Right-of-Way
BA, BB, BF	Borrow Pits	FC-FF	Minor Right-of-Way
BD, BG	Bladed Slopes	GA-GF	West Control (Lower Terrace)
CA-CG	Road	HA-HB	Major Right-of-Way
DB-DG	West Control (Upper Terrace)	IA-IB	Stream Bed Control

Telephone, Minor and Major Rights-of-Way and the Road were subdivided into five, four, three and seven stands respectively. Each borrow pit and bladed slope provided one stand, for a total of five.

Vegetation sampling was performed within 340 nested quadrats, the majority of which were positioned along randomly located transect lines (Figure 3.1). A total of 50 transect lines were generated. Thirty-five crossed the Road, while the remaining 15 bisected the Major Right-of-Way (Figure 3.1). Additional quadrats were located with the aid of a random numbers table in the three Borrow Pits and Bladed Slope D. These latter quadrats were added on the basis of Species-Area Curve results (Mueller-Dombois and Ellenberg 1974).

3.2.2 Quadrat Location

The length of the transect line cutting across each disturbance was measured and subdivided into sequentially numbered 2m-wide portions. Quadrats were then located on these lines with the aid of a random numbers table (Figure 3.1). The undisturbed control vegetation was treated similarily, although each 5 m interval was demarcated and numbered instead of 2m intervals used on the disturbances Tree parameters in the disturbances were also estimated in 25 m^2 quadrats, although the positioning of each quadrat was determined by the shape and orientation of the disturbance. Species area curves were employed to decide sampling intensity and, hence, the number of quadrats per sampling area (Gauch 1982). Each transect line contained 1 or 2 quadrats per sample area corresponding to disturbed and control sites, respectively.

3.2.3 Vegetation Sampling

Estimates of the folowing characteristics were conducted within each nested quadrat:

1) % cover and frequency of vascular and non-vascular plant species and

2) stem density of all tree and erect shrub species.

Cover was estimated visually to the nearest percent (Mueller-Dombois and Ellenberg 1974, Gauch 1982). Frequency and percentage cover were estimated once during the growing

Table 3.1: Location and Number of Stands and Quadrats in Controls and Disturbances Milepost 40, Dodo Valley, N.W.T.

Location	Stands	Quadrats
East Talus Control	7	70
West Terrace Control (Upper Terrace)	6	58
West Terrace Control (Lower Terrace)	6	60
Stream Bed Control	2	20
Subtotal	21	208
Borrow Pit A	1	8
Borrow Pit B	1	9
Borrow Pit F	1	7
Bladed Slope D	1	8
Bladed Slope G	1	5
Road	7	35
Telephone Line Right-of-Way	5	25
Minor Right-of-Way	4	20
Major Right-of-Way	3	15
Subtotal	24	132
TOTAL	45	340

Table 3.2: Quadrat Dimensions and Plant Species Measurements on Disturbances and Controls Milepost 40, Dodo Valley, N.W.T.

Quadrat Size (m)	Plant Species	Measurement
5 X 5	Tree	Cover (%) Frequency (%) Density (stems/m^2) Height (dm) DBH (cm) Age (years)
2 X 5	Understory Vascular *	Cover (%) Frequency (%)
1 X 1	Non-vascular	Cover (%) Frequency (%)
	Erect Shrub	Density (stems/m^2) Cover (%)

* Understory Vascular = Shrubs, Forbs, Pteridophytes, Graminoids.

season for all plant species in each control and disturbance vegetation sample. This intensive vegetation survey commenced on July 18, 1983, after the deciduous plant species had fully leafed out, (fully expanded with a leathery texture), and was completed on August 7, 1983.

Samples of vascular and non-vascular plant species were collected from areas outside the quadrats, pressed, and taken to Edmonton for confirmation of provisional field identifications. Vascular plant specimen verifications were completed by Linda Kershaw according to *Porsild and Cody's Flora of the Continental N.W.T.* (1980). Derek Johnson of the Northern Forestry Centre, Edmonton, Alberta, verified the provisional non-vascular plant taxa identifications.

Tree and Shrub Samples

The largest, and presumably oldest, trees and shrubs were sampled for aging from each stand. This was performed in order to determine mean and maximum ages of the oldest individuals of species on the undisturbed controls and disturbances. These data were analyzed to determine:

1) the proportion of samples which survived disturbances;

2) the dates of colonization;

3) the source of woody plants - whether trees and/or shrubs were transported onto the disturbances during or following construction.

A total of 157 shrub root crowns were collected and aged. An additional 209 samples, including representatives of all four tree species identified in the study area, were also harvested in the tree and shrub layers.

3.2.4 Environmental Factors

Factors of the environment such as precipitation, soil moisture, soil temperature, soil chemistry, physical properties of the soil, etc. contribute to vegetation responses to disturbance.

Climate

Local air temperature was monitored daily with paired alcohol-mercury max-min thermometers (i.e. one max thermometer and one min thermometer) located in the middle and at each end of the study site. They were shielded from direct sunlight with ventilated white plastic containers.

Wedge-shaped rain gauges were located in open areas at a 1.5 m height within one m of each max-min site, so that precipitation could be monitored daily.

Soil Climate

Soil moisture and temperature were measured along transect lines at 10 cm depth from the surface at all sites. This standard depth allowed for comparisons of soil temperature and moisture between sites. Soil moisture was measured using Soiltest fiberglass soil moisture blocks, which also contained a thermister for temperature readings. A soiltest MC-300 series soil moisture-temperature meter was used to take the readings. This meter was broken in early July. As a consequence, a YSI probe was also used to measure soil temperatures at 10 cm depth, while soil moisture was determined gravimetrically.

"Soil climate" was defined as the mean moisture and temperature values at 10cm depth. Sampling for soil moisture commenced June 30, and for soil temperature on July 6. Both of these soil characteristics were measured at least three times over the field season, in each stand.

Soil climate values were grouped into Control (i.e. East Talus Control, West -- Upper and Lower Terraces), Disturbance (Telephone Line, Minor and Major Rights-of-Way, Road), or Disturbance type (Borrow Pits and Bladed Slopes), and then averaged. The means for each Control and Disturbance category were then used as soil temperature and moisture indices for subsequent non-parametric statistical analyses. The soils of the Streambed Control were not described nor were any soil climate measurements obtained from them.

Soils

Transect lines were randomly placed across each stratified vegetation sampling area in a central location in order to describe relief. The relief was measured with an Abney level and range pole at 10cm intervals.

With the exception of the borrow pits, one bladed surface, and the Streambed control, one soil pit was dug in each stand and sampled at the end of the field season (Figure 3.1). Two soil pits were dug in the borrow pits, one on the floor, the other on the headwall, while the large bladed surface was sampled at both the slope top and base. The streambed soils were not described nor were any samples obtained from them. Horizons were described in terms of thickness, colour, structure, stoniness, and rooting depths. Soil samples were collected on an horizon basis from each site on the last two days of the field season and transported in plastic bags to the laboratory for analyses.

3.3 Laboratory Analyses

3.3.1 Soil Analyses

Soil samples were numbered sequentially and then sub-divided into two portions for subsequent physical and soil reaction (pH) analyses. Sub-samples for soil reaction were stored at -27 °C, while the sub-samples for determinations of physical characteristics were air dried and stored in paper bags.

Soil Reaction

Frozen samples were thawed and the moisture content determined gravimetrically (McKeague 1978). Moisture content was expressed on an oven-dry weight basis. The pH of the soil samples was measured with a combination electrode on a saturated soil paste (Richards 1954).

Physical Analyses

Soil physical properties were analyzed for organic matter content and particle size distribution. Organic matter content was assessed using a modified Walkley-Black procedure (McKeague 1978) and expressed as a percentage of the oven-dry weight. The hydrometer method was used to estimate the particle size distribution of soil samples following digestion of the organic matter fraction with H_2O_2 (McKeague 1978). Particle size determinations were performed on all soil samples not classified as organic (i.e. less than 30%) according to the C.S.S.C. (1977).

3.4 Disturbance Regime Variables

Each disturbance was described in terms of:

1) spatial extent;

2) terrain sensitivity;

3) magnitude.

3.4.1 Spatial Extent

The spatial dimensions of each CANOL No. 1 Project disturbance were described. The parameters were length, width, area, perimeter, and perimeter to area ratio.

3.4.2 Terrain Sensitivity

The terrain of the East and West Controls were classified for sensitivity to disturbance. Kurfurst's (1973) model was used for this purpose (Appendix 1). His system enabled classification of the terrain into one of six sensitivity units. Unit one represented the most stable site. Terrain which contained characteristics of two units was assigned an intermediate value. This procedure involved several steps:

1) The proportion of the total area occupied by each of the two terrain sensitivity units was estimated;

2) The terrain was then classified with a two digit number. The spatially dominant unit was listed first, for example: Unit 1 : Unit 2.

3) This value was converted into a single number by double weighting the first digit in order to emphasize its dominance e.g.

i) Unit 1 : Unit 2 = 1:2

ii) (1+1)/3 +2/3 = 1.3

3.4.3 Magnitude

Magnitude was composed of two elements, intensity and severity.

Intensity

An index value which ranged from 1, least intense, to 10, most intense, was assigned to each disturbance. These values were based upon a model produced by Heginbottom (1973). It ranked disturbing agents (e.g. bulldozer) and processes (e.g. compaction) in terms of the intensity of their initial impact (Appendix 2). The model was modified to include agents and processes associated with road construction and borrow pit development (Appendix 2).

The general categories of intensity depicted in Heginbottom's (1973) model are not exact. They do, however, provide a rough approximation of the impacts that each perturbation agent can inflict upon an ecosystem.

Severity

Disturbance Severity was calculated in two ways:

1) shrub density reduction;

2) microtopographical change.

1) shrub density reduction

Disturbance severity on the vegetation was estimated by calculating the reduction in erect shrub densities attributable to CANOL No. 1 Project disturbances. The greater the reduction, the more severe a disturbance. These values were expressed as % shrub destroyed.

No density values were available for the periods immediately preceding and following CANOL construction. Shrub density reduction had to be estimated. Two factors were used:

1) knowledge of construction practices and

2) shrub ages.

Calculation of shrub densities were as follows. Road, Borrow Pit and Bladed Slopes were sites of complete vegetation destruction. Post-disturbance densities were, therefore, equal to zero. Reductions in shrub density were 100%. Calculations for the bladed trails was more complex, as not all shrubs were killed. A conversion factor, based upon the proportion of destroyed shrubs was used:

1 - (No. of Samples Pre-dating 1942 / Total N) x 100

2) microtopographical change

The factor quantified in order to assess the severity of the perturbation associated with the CANOL Project to the soil was microtopographical change. This characteristic was estimated to the nearest centimetre. It was a measure of the average relief between crests and troughs within 2 m by 5 m quadrats. Four grades of microtopography were distinguished (Table 3.3).

Microtopography for each site was determined by converting the W, M, S, and E codes for each quadrat to their respective midpoints (cm). The average value for each disturbance and control was then calculated. Changes in microtopography were then estimated by calculating the difference between the disturbance value and the appropriate control. The greater the change in microtopography the more severe the disturbance. .

3.5 Data Manipulation and Analyses

Table 3.3: Grades of Microtopography

Milepost 40, Dodo Valley, N.W.T.

Grade	Symbol	Relief (cm)	Midpoint (cm)
Weak	W	0 - 5	2.5
Moderate	M	6 - 25	15.5
Severe	S	26 - 50	38.0
Extreme	E	51 - 100 *	75.5

* Note: This height was the maximum observed value.

3.5.1 Floristic Data

Multivariate Analyses

A computer program, SEADYN (Department of Botany, University of Alberta) was employed to convert the cover data for 340 species by quadrat matrices into 45 species by stand matrices. This conversion produced an average cover value for each species in a stand.

These 45 matrices, representing the Control and Disturbance stands, were classified using Two-Way Indicator Species Analysis (TWINSPAN) and Detrended Correspondence Analysis (DECORANA) (Hill 1979a and 1979b). TWINSPAN is a Polythetic Divisive Classification technique that polarizes the most dissimilar samples (i.e. species by stand matrices). It does so by placing them at extreme ends of a classification table (Gauch 1982). Hence, samples which are similar to one another in terms of species composition and abundance, occur together in the table. Hierarchical relationships between the stands are depicted with a dendrogram which also assists in stand comparisons.

DECORANA, an ordination technique, expresses mathematical relationships between vegetation stands in terms of distance (Hill 1979b). These ordination scores for the 45 stands were plotted in two-dimensional space. The scores were also used to test for non-parametric statistical correlations with disturbance regime and abiotic variables.

These multivariate analyses were initially used to produce plant communities from the 21 control stands only. Following this, all 45 stands were analyzed. Disturbance stands which were incorporated into a control plant community or cluster were considered "recovered" in terms of species composition and/or abundances. Those which produced a separate cluster had not recovered. Determination of which factor (species composition or abundance) was primarily responsible for cluster formation was assessed using CLUSTAN (Wards Method).

This program uses a sequential, agglomerative, hierarchial multivariate analysis. Analyses were performed with the data in two forms, "Raw" and "Standardized". Stand dissimilarity indices produced from Raw data are primarily determined by species abundances, while Standardized analysis emphasizes species composition. The larger the index, the greater the difference between the stands. Abundance data would, for example, be considered more important if the Raw data index was substantially larger than the value derived from standard data.

Sørensen's Index of Floristic Similarity

Re-establishment of vegetation on CANOL disturbances was assessed, in part, by estimating the floristic similarities among disturbed and control communities. Species presence-absence data from the Control and Disturbed communities were compared by a binary coefficient, Sørensen's Index.

Sørensen's Index was used for the purpose of comparing the species compositions of disturbances with control plant communities. It was calculated as follows:

$IS = 100(2C/(A + B))$

where,

$C =$ number of species common to both communities;

$A =$ total number of species on control community;

$B =$ total number of species on disturbed community.

Plant Species Structure

The long-term effects of CANOL construction activities in Dodo Valley on plant species structure were evaluated through determination of species richness (R) and calculation of Simpson's Index of Dominance Concentration (C). Species richness is defined as the number of species in a sample (Mueller-Dombois and Ellenberg 1974). Simpson's Index estimates species equitability, and is based on species abundances (% cover) and composition (Whittaker 1975); it is deemed to be a measure of how evenly abundance is distributed among species (Whittaker 1975). It was calculated as follows:

$$C = \sum_{i=1}^{s} p_i^{\,2} = \sum_{i=1}^{s} \left[\frac{n_i}{N}\right]^2$$

The letters are defined as follows: $N =$ importance value for all species in the sample; $n_i =$

importance values of S individual species; p_i = relative importance values for these same species.

The index attains a maximum value which approaches 0.99. This occurs if virtually all of the cover is contributed by one taxon. A zero value is approached if all species have the same cover (i.e. there is an even distribution of abundance). The value of C is primarily determined by the dominant species (Whittaker 1975). The minimun value of C = 1/R, where R = species richness.

All indices are sensitive to sampling intensity (Goodman 1975, Mueller-Dombois and Ellenberg 1974). Sample intensity, which was based on the size of the area being surveyed and complexity of the vegetation (i.e. spatial heterogeneity), ranged from five quadrats per stand on the Bladed Trails and Road, to 10 quadrats per stand in the Controls. Floristic information from five sub-samples (quadrats) were randomly selected from the total data set of each stand. This was done in order to standardize sampling intensity prior to calculation of the indices. Since the number of stands used to describe the vegetation for the Controls and Disturbances ranged from one (e.g. Borrow Pits) to twelve (e.g. West Side Undisturbed Control), the mean R and C values per stand for each Control and Disturbance were also calculated.

3.5.2 Tree Size Structure

Tree size structure diagrams were constructed for each control and for those disturbances deemed to have relatively complex structures. These diagrams were based upon the Diameter at Breast Height (DBH) values obtained from each tree that had attained a minimum DBH of 1.5 cm and height of 2 m.

4. RESULTS - CONTROL AND DISTURBANCE CHARACTERISTICS

4.1 CONTROLS

4.1.1 Vegetation

Control vegetation stands were located east of the road on a relic talus slope, west of the road on two different aged alluvial terraces, and in an intermittent stream bed. The stream bed control was selected so that floristic comparisons could be made between natural and CANOL No. 1 Perturbations. All other control stands were classified as undisturbed.

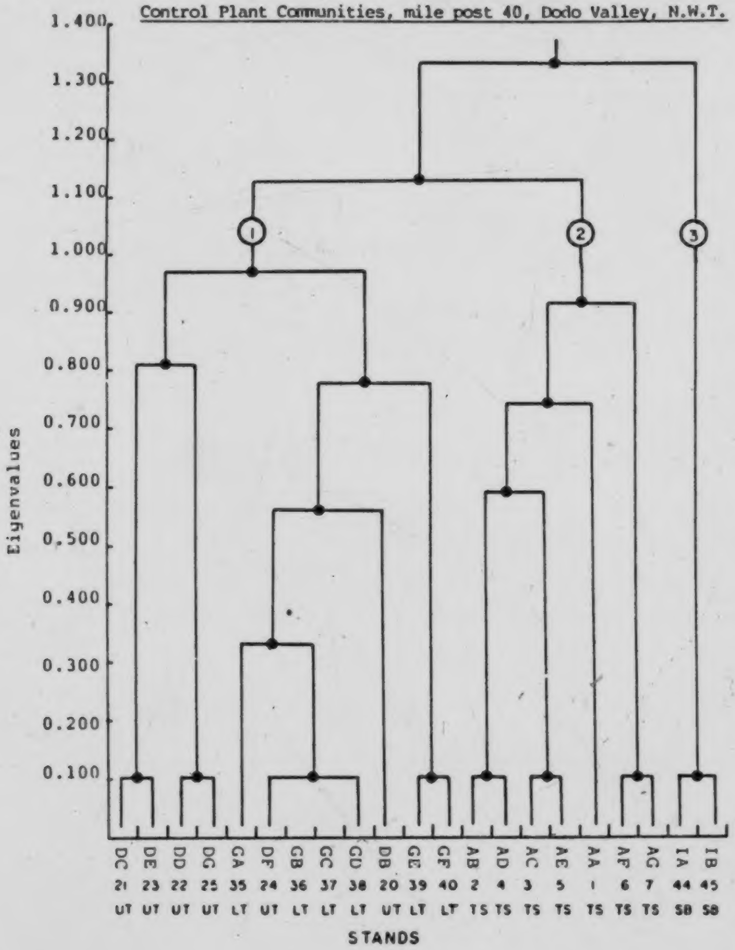
Control plant communities were selected primarily from TWINSPAN and DECORANA analyses (Figures 4.1 and 4.2).

Stands located on the relic talus slope and in the intermittent stream bed produced two distinctive clusters (Figures 4.1 and 4.2). Their designation as plant communities was, therefore, straightforward. Classification of the stands on the two alluvial terraces was more complex.

In spite of differences in surface age and soil type the two imperfectly- drained terraces appeared to support similar vegetation. The dendrogram, however, strongly suggested the presence of two plant communities. Each community was not confined to a single terrace, however. In contrast, the ordination diagram indicated only one community.

Other data supported the ordination results, thus favouring a single alluvial terrace community: 1) evergreen and deciduous shrubs, feathermosses and reindeer lichens typified the understory of both terraces; 2) tree ages were comparable. For example, *Picea glauca* trees on the higher, and therefore, older terrace had maximum and average ages of 401 and 210 years respectively (Appendix 3). Their counterparts on the lower terrace were 380 and 198 respectively; 3) plant species richness for the older ($R=110$) and younger ($R=102$) terraces were close in value; 4) eleven of the fifteen most abundant taxa were common to both terraces; 5) the Sørensen's Index of Floristic Similarity at 0.81 indicated a strong affinity between the two controls; 6) There was no significant ($p >> 0.05$) difference in total plant

Figure 4.1: Classification of West Terrace (1), East Talus (2) and Stream Bed (3) Control Plant Communities, mile post 40, Dodo Valley, N.W.T.



Legend

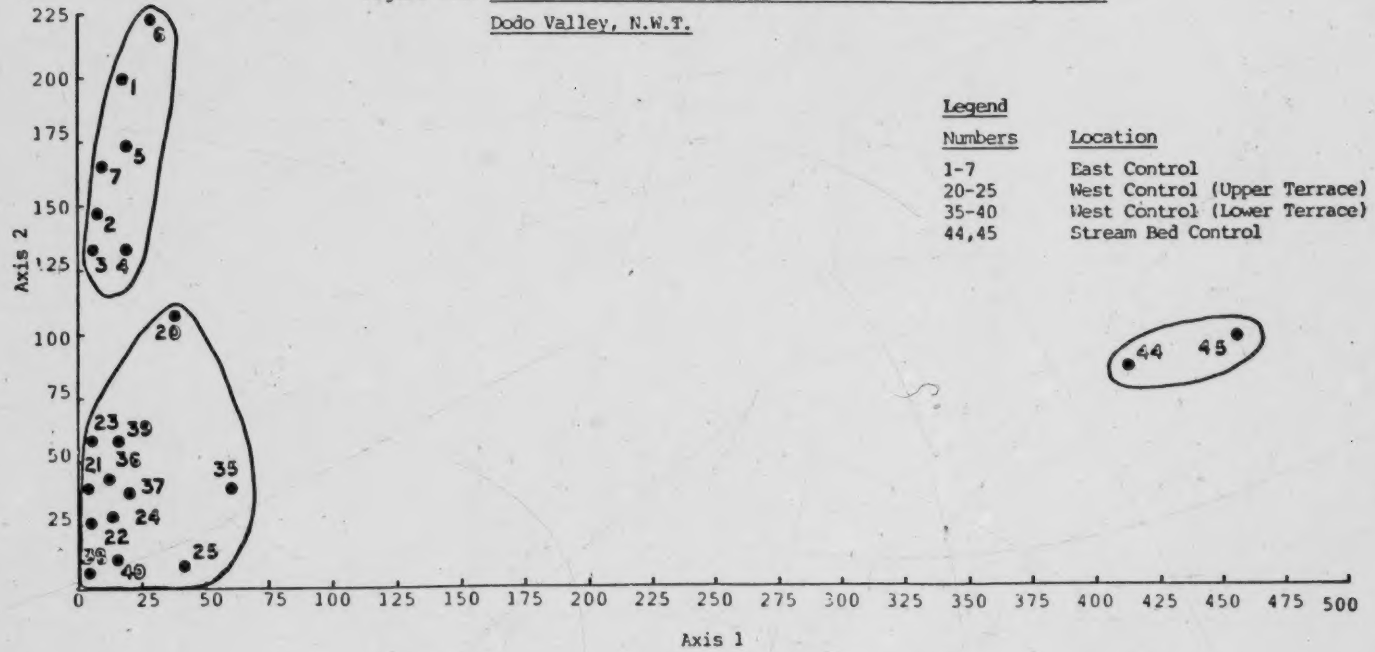
Location

AA-AG = East Talus
IA-IB = Stream Bed
DB-DG = West Terrace (Upper)
GA-GF = West Terrace (Lower)

Landform

UT = Upper Terrace
LT = Lower Terrace
TS = Talus Slope
SB = Stream Bed

Figure 4.2: DECORANA Ordination Plot of Control Stands at mile post 40 Dodo Valley, N.W.T.



Legend

Numbers	Location
1-7	East Control
20-25	West Control (Upper Terrace)
35-40	West Control (Lower Terrace)
44,45	Stream Bed Control

cover: the upper terrace averaged 105% (n=58) while the lower one was 96% (n=60); 7) DECORANA scores for the first three axes were not significantly different according to the Mann-Whitney U Test (Sokal and Rohlf 1981).

In summary, three control plant communities were selected. The name assigned to each community was based on the species which dominated the tree, shrub, herbaceous and non-vascular strata, and on its location. The three plant communities were:

1)East Talus -- *Picea glauca/Dryas integrifolia/Carex scirpoidea/Cladina mitis* Control;

2)West Terrace -- *Picea glauca/Ledum groenlandicum/Festuca altaica/Hylocomium splendens* Control;

3)Stream Bed -- *Populus balsamifera/Dryas drummondii/Epilobium latifolium/Campylium stellatum* Control.

For brevity these three controls may be referred to as East Talus, West Terrace and Stream Bed Controls throughout the thesis.

East Talus -- *Picea glauca/Dryas integrifolia/Carex scirpoidia/Cladina mitis* **Control**

The seven contiguous stands which comprised the East Talus Control were situated on a 16° relic talus slope with a west-facing exposure (Plate 10). Generally, the vegetation dominating this site was equivalent to the *Hylocomium splendens/Picea glauca* association (Hettinger 1973), Gnarled white spruce and larch/*Dryas/Cetraria* (Reid 1974) and the sub-alpine *Picea glauca/Larix laricina/Dryas integrifolia* unit of Reid and Janz (1974).

The vegetation was characterized by open and mixed stands of *Picea glauca, Picea mariana* and *Larix laricina*; cover of the tree stratum was 3%, total plant cover was 51% and tree density was 119 stems ha^{-1} (Figure 4.3). The dominant *Picea glauca* trees exceeded 180 years (Appendix 3).

The species rich (R=113) understory had well-developed medium shrub, dwarf shrub, bryophyte and lichen strata. Abundant species in the understory shrub layers were *Dryas integrifolia, Betula glandulosa, Arctostaphylos uva-ursi, A. rubra, Potentilla fruticosa,*

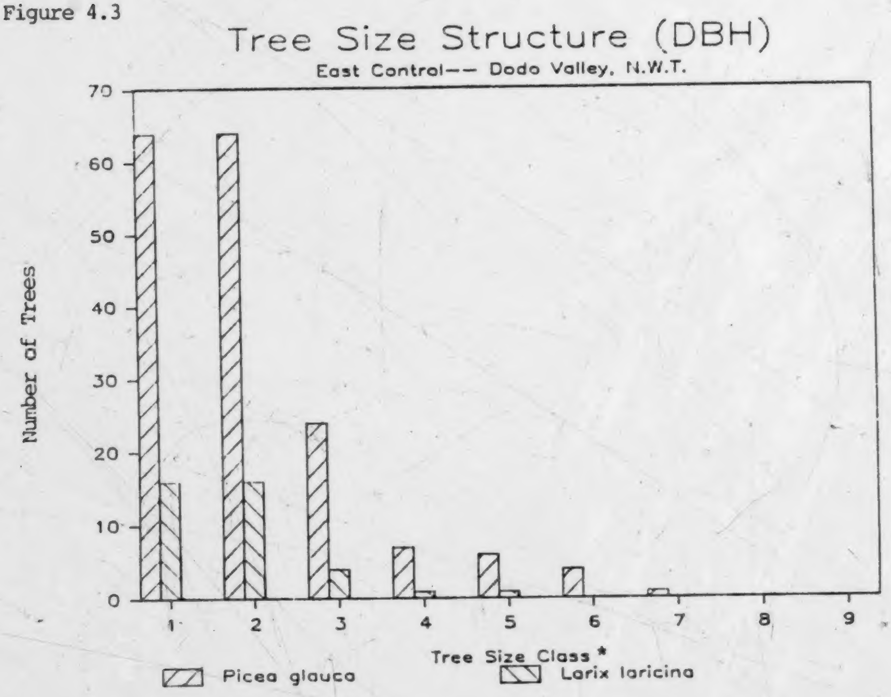
Plate 4.1 East Talus -- *Picea glauca/Dryas integrifolia/ Carex scirpoidea/Cladina mitis* Control
Note the open-canopy Picea spp. layer and steeply sloping, west facing terrain.
July 20, 1983

Table 4.1: East Talus Control--*Picea glauca/ Dryas integrifolia/Carex scirpoidea/Cladina mitis*
Major Species Per Stratum
Milepost 40, Dodo Valley, N.W.T.

STRATUM	SPECIES	% FREQUENCY	% COVER
TREE (over 2m)	*Picea glauca*	75.00	2.90
	Larix laricina	24.00	0.50
TALL SHRUB (over 1m)	*Picea mariana*	15.70	1.15
	Picea glauca	82.90	0.65
	Alnus crispa	10.00	0.66
MEDIUM SHRUB (10cm - 1m)	*Betula glandulosa*	77.00	3.32
	Potentilla fruticosa	93.00	1.19
	Vaccinium uliginosum	66.00	0.99
	Rhododendron lapponicum	84.00	0.91
DWARF SHRUB (0 - 9cm)	*Dryas integrifolia*	97.00	6.87
	Arctostaphylos uva-ursi	81.00	3.13
	Arctostaphylos rubra	91.00	1.35
	Salix myrtillifolia	17.00	0.14
FORB			
Broad leaf herbaceous*	*Anemone parviflora*	85.70	0.28
	Hedysarum alpinum	31.40	0.23
	Tofieldia pusilla	54.30	0.14
	Thalictrum alpinum	54.30	0.13
Graminoid	*Carex scirpoidea*	87.10	1.85
	Elymus innovatus	54.30	0.81
	Festuca altaica	40.00	0.32
	Calamagrostis neglecta	27.10	0.23
NON-VASCULAR			
Bryophyte	*Hylocomium splendens*	32.86	2.81
	Rhytidium rugosum	42.86	1.41
	Drepanocladus uncinatus	27.14	0.82
	Hypnum bambergii	24.29	0.70
Lichen	*Cladina mitis*	82.60	6.77
	Cetraria islandica	62.90	1.18
	Cetraria nivalis	31.40	0.79

*Includes pteridophyte species.

Figure 4.3



*

Class:	1	2	3	4	5	6	7	8	9
Range (cm):	1-3.9	4-6.9	7-9.9	10-12.9	13-15.9	16-18.9	19-21.9	22-24.9	25-27.9

Vaccinium uliginosum and *Rhododendron lapponicum* (Table 4.1, Appendix 4). Common forb species included *Anemone parviflora, Hedysarum alpinum, Tofieldia pusila,* and *Thalictrum alpinum*. The main sedges and grasses were *Carex scirpoidea, Elymus innovatus, Festuca altaica* and *Calamagrostis neglecta*. *Cladina mitis* was the dominant non-vascular taxon. Other abundant ground cover species were *Hylocomium splendens* and *Cetraria islandica* (Table 4.1).

West Terrace -- *Picea glauca/ Ledum groenlandicum/ Festuca altaica/ Hylocomium splendens* Control

The West Terrace Control plant association was composed of twelve stands located on two alluvial terraces (Plate 11). The vegetation was similar to Hettinger's (1973) *Picea glauca* low and high terrace associations, as well as, the Riparian spruce feathermoss unit (Wallace 1972), and the *Picea glauca/ Hylocomium splendens* association (Reid and Janz 1974).

Canopy cover of the West Terrace Association was over 6% and tree density was 180 stem ha^{-1}. This control was classified as open canopied, but it was considerably more closed than the East Talus Association which had 50% less canopy cover and a tree density of 120 stem ha^{-1} (Figures 4.3 and 4.4).

Although the 94 vascular and 31 non-vascular plant species exceeded the East Talus total by eleven (Appendix 4), the average number of species per quadrat were identical at 26. Total plant cover at 100% was twice that of the East Talus Control. The tree, medium and dwarf shrub layers, as well as the lichen and bryophyte strata, were well-developed in the West Terrace Community.

This control had the most complex tree size structure of all the sites (Figure 4.3). The overstory was dominated by *Picea glauca*. *Larix laricina* and *P. mariana* occurred occasionally in hygric microsites of the upper terrace (Table 4.2)

In general, the shrub taxa on the West Control were more abundant than their counterparts on the East Talus Control. Important shrub species were *Ledum groenlandicum, Vaccinium ulginosum* and *Betula glandulosa*. *Arctostaphylos rubra, Salix myrtillifolia* and *Vaccinium vitis-idaea* were substantially more abundant on this control than the East, while

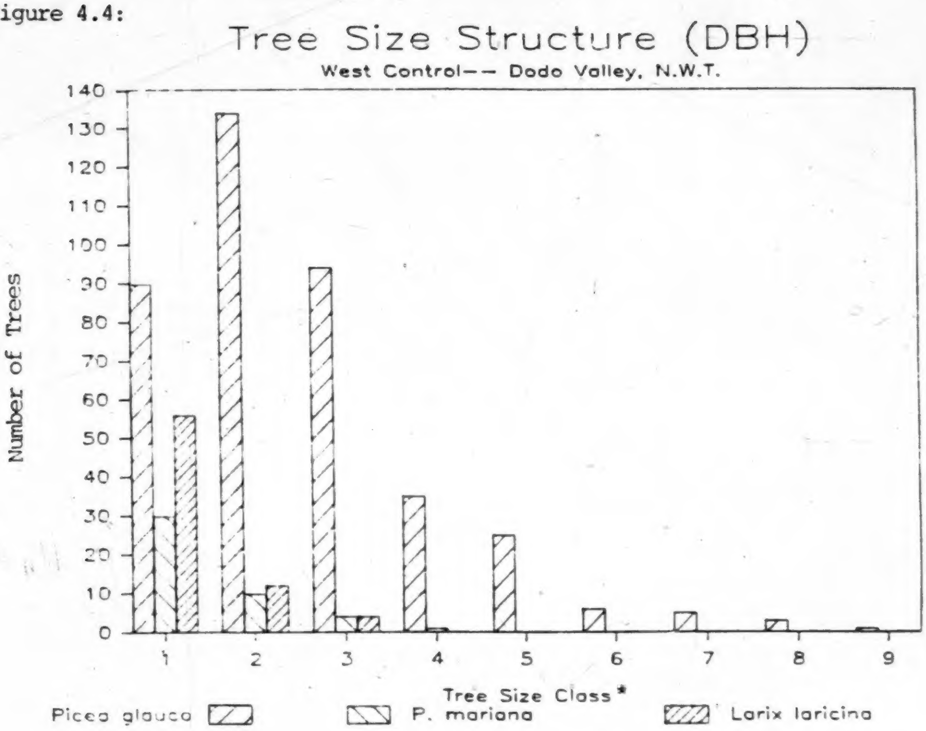
Plate 4.2 West Terrace -- *Picea glauca/Ledum groenlandicum/Festuca altaica/Hylocomium splendens* Control Note the open canopy Picea spp. layer and level terrain. The shrub layer is also well-developed. July 31, 1983

Table 4.2: West Terrace Control-- *Picea glauca/Ledum groenlandicum/ Festuca altaica/Hylocomnium splendens*
Major Species Per Stratum
Milepost 40, Dodo Valley, N.W.T.

STRATUM	SPECIES	% FREQUENCY	% COVER
TREE (over 2m)	*Picea glauca*	95.0	0.40
	Larix laricina	22.0	4.40
	Picea mariana	21.0	0.70
TALL SHRUB (over 1m)	*Alnus crispa*	19.50	1.24
	Salix alaxensis	30.50	1.15
MEDIUM SHRUB (10cm - 1m)	*Ledum groenlandicum*	99.10	3.60
	Vaccinium uliginosum	92.40	3.50
	Betula glandulosa	75.40	3.10
	Potentilla fruticosa	78.00	0.80
DWARF SHRUB (0 - 9cm)	*Arctostaphylos rubra*	86.40	2.56
	Dryas integrifolia	72.00	2.12
	Vaccinium vitis-idaea	88.10	1.42
	Salix myrtillifolia	56.80	1.24
FORB Broad leaf herbaceous*	*Equisetum arvense*	38.10	1.37
	Hedysarum alpinum	37.30	0.45
	Saussurea angustifolia	26.30	0.36
	Equisetum scirpoides	47.50	0.28
Graminoid	*Festuca altaica*	82.20	1.68
	Carex scirpoidea	70.30	1.13
	Carex membranacea	13.60	1.13
	Elymus innovatus	41.50	0.43
NON-VASCULAR Bryophyte	*Hylocomium splendens*	68.60	26.66
	Pleurozium schreberi	50.90	4.95
	Rhytidium rugosum	59.30	4.12
	Plagiomnium ellipticum	20.30	1.61
Lichen	*Cladina mitis*	70.40	12.56
	Cladina stellaris	7.70	0.63
	Cetraria islandica	23.70	0.42
	Cetraria cucullata	27.10	0.38

*Includes pteridophyte species.

Figure 4.4:



*

Class:	1	2	3	4	5	6	7	8	9
Range (cm):	1-3.9	4-6.9	7-9.9	10-12.9	13-15.9	16-18.9	19-21.9	22-24.9	25-27.9

Dryas integrifolia was less common. The species-rich herb layer with 59 taxa was dominated by graminoids. *Festuca altaica, Carex scirpoidea* and *C. membranacea* all had high covers (Table 4.2). *Equisetum arvense*, a horsetail species, common on river terraces all over the Boreal and Subarctic zones, was the major forb.

The lichen stratum of the West Terrace Control had a comparable number of species as the East Talus (14 and 13 respectively), but a much lower frequency (77% and 96%). Mean cover was higher on the West Control by over 4%, however. *Cladina mitis*, which was again the dominant lichen, accounted for the difference.

Total bryophyte cover was over 6.5 times greater on the West Control than the East. This layer was the best-developed, as its 17 taxa attained 100% frequency and a total cover of 46%. The two most abundant taxa were *Hylocomium splendens* and *Pleurozium schreberi* (Table 4.2). *Hylocomium splendens* had ten times the cover on the West compared with the East Control. *Rhytidium rugosum*, a calciphyte taxon, was also common.

Stream Bed -- *Populus balsamifera/ Dryas drummondii/ Epilobium latifolium/Campylium stellatum* **Control**

The vegetation was poorly developed in this control (Plate 12). Only 48 species were identified and, with the exception of the dwarf shrub stratum, no layer had a cover total greater than 2.5%.

The sparse tree layer was composed of *Populus balsamifera* and *Picea glauca* trees (Table 4.3). These species were also present in the equally sparse tall shrub stratum (Appendix 4). *Salix alaxensis* was the principal taxon of this layer. Medium shrubs were also sporadically distributed, and low in cover. One taxon, *Shepherdia canadensis*, dominated. The well-developed dwarf shrub stratum contained eight species, had 100% frequency and a cover of 35%. This layer and the plant community as a whole were dominated by *Dryas drummondii. Empetrum nigrum, Arctostaphylos rubra* and *A. uva-ursi* were also present.

The ubiquitous (frequency = 75%) and relatively numerous (R=13) forb species had a combined cover of only 2.3%, with *Epilobium latifolium* and *Hedysarum boreale* the two

Plate 4.3 Stream Bed -- *Populus balsamifera/Dryas drummondii/ Epilobium latifolium/Campylium stellatum* Control
Note the sparse Populus balsamifera tree layer and extensive Dryas spp. mat.
August 8, 1983

Table 4.3: **Stream Bed Control-*Populus balsamifera/Dryas drummondii/ Epilobium latifolium/Campylium stellatum***
Major Species Per Stratum
Milepost 40, Dodo Valley, N.W.T.

STRATUM	SPECIES	% FREQUENCY	% COVER
TREE (over 2m)	*Populus balsamifera* *Picea glauca*	60.00 55.00	0.74 0.31
TALL SHRUB (over 1m)	*Salix alaxensis* *Alnus crispa*	60.00 15.00	0.76 0.08
MEDIUM SHRUB (10cm - 1m)	*Shepherdia canadensis*	25.00	0.38
DWARF SHRUB (0 - 9cm)	*Dryas drummondii*	100.00	35.30
FORB Broad leaf herbaceous*	*Epilobium latifolium* *Hedysarum boreale*	55.00 55.00	1.16 0.91
Graminoid	*Trisetum spicatum* *Elymus innovatus*	85.00 25.00	0.80 0.41
NON-VASCULAR Bryophyte	*Campylium stellatum*	15.00	0.53
Lichen	*None*	N/A	N/A

*Includes pteridophyte species.

most abundant species. Graminoids were sparse but well-distributed throughout the community. *Trisetum spicatum* and *Elymus innovatus* were the major taxa (Table 4.3).

There were no lichens, and bryophytes were sporadic. Two principal bryophytes were calciphytes: *Campylium stellatum* and *Ditrichum flexicaule*. Bryum spp. were also relatively abundant.

Of interest was the prominence of *Dryas drummondii*, *Alnus crispa* and *Shepherdia canadensis*, which are nitrogen-fixing shrubs (Appendix 4). With the addition of two legumes, *Heysarum alpinum* and *H. boreale*, the total plant cover accounted for by nitrogen-fixers was 87%. This suggested that the stream bed was a relatively nutrient poor site.

4.1.2 Soils

East Talus -- *Picea glauca/ Dryas integrifolia/ Carex scirpoidea/ Cladina mitis* **Control**

The East Talus Control was located on a 16° fossil scree slope. Eutric Brunisols were the major soil type, although Cumulic Regosols were also present (Appendix 5). These latter soils developed at sites where slope movements buried organic horizons.

Eutric Brunisols:

Due in part to the variable microtopography, LFH horizons ranged in thickness from 0 to 50 cm. Surface soil reaction also exhibited marked variation, ranging from medium acid (pH of 5.9) in Stand C, to mildly alkaline (7.7) in Stand F. The pH values increased with depth at all sites, with reaction generally ranging from mildly to moderately alkaline (7.7 to 8.1) (Appendix 5).

Soil structure was poorly developed with most horizons rated as amorphous or weakly granular. Several horizons at depth (50 cm) exhibited weak, fine, blocky structure. This was due to the localized pockets of soil with comparatively high clay contents (35 to 40%). All soils were moderately (50% by volume), to excessively stony (75 to 90%), with angular and sub-angular forms ranging in size from 2 to 40 cm. The soil matrix was generally fine-textured, as silt loams and clay loams predominated. This fine texture may have reduced infiltration rates sufficiently enough to have produced faint gleying characteristics at the B-C horizon boundary. Soil colours here were very dark gray brown to gray, with chromas of 2 or less. Faint mottling was infrequently observed.

West Terrace -- *Picea glauca/ Ledum groenlandicum/ Festuca/ Hylocomium splendens* Control

The West Terrace Control encompassed two alluvial terraces. Orthic Gleysols dominated the higher terrace, while gleyed Cumulic Regosols characterized the soils of the lower one. Eutric Brunisols occupied relatively small portions of both terraces.

Orthic Gleysols (Upper Terrace):

The dominance of Orthic Gleysols on the older terrace indicated that the soils of this terrace had been saturated with water and affected by reducing conditions for extended periods of time during the year (CSSC 1977). LFH thicknesses varied considerably, from 2 cm in Stand G to 70 cm in Stand F. Generally speaking, the LFH grew shallower from north to south, and as the Road was approached (i.e. from east to west). The thickest organic horizons were located in the northwest section of the terrace. The parent material was primarily calcareous alluvium, with a reaction of 7.8 in the Ck horizon. Surface layers were acidic (6.0 to 6.5). With the exception of clay lenses, which were medium sub-angular blocky, structure was weakly developed or amorphous (Appendix 5). Soil texture was dominated by sandy loams and clay loams. Although the surface was free of stones and gravel, sub-angular to rounded 1 to 50 cm stones usually occupied 90 % of the substrate by volume within 20 to 30 cm of the mineral surface. Gleying was prominant and evidenced by many coarse, distinct mottles, gray and grayish brown soil colours, and chroma values of 2 or less. These characteristics were frequently observed in the upper mineral horizon. This indicated that a relatively high and persistent water table has been present.

Gleyed Cumulic Regosols (Lower Terrace):

Periodic flooding deposited alluvium onto the soil surface of the younger terrace, and produced a profile with buried Ah and H horizons (Table 5.9). In addition, surface LFH layers were either absent or thin (7 cm), and mottling was evident. As a result, gleyed Cumulic Regosols typified the soil of the younger terrace. This soil type is characteristic of floodplain and alluvial fan soils (Tarnocai 1973).

Organic horizons were thin (less than 7 cm), but had a slight increase in depth towards the northwest. Soil structure was poorly developed, as most horizons were amorphous or weakly granular. Texture was relatively coarse as sandy loams and loamy sands predominated. Rounded to sub-angular 3 to 30 cm stones displayed considerable spatial variability, in terms of their location in the profile. The top of the stony layer below the mineral surface ranged in depth from 15 to 72 cm. Soil surface reaction appeared strongly influenced by organic matter, as pH ranged from 6.2 to 8.0. Slightly acid reactions occurred in Ah horizons, while more basic reactions were characteristic of B horizons.

Eutric Brunisol (Lower Terrace):

One stand, GB, was underlain by an Eutric Brunisol soil (Appendix 5). The wavy LFH horizon was from 10 to 20 cm thick, and contained visibly abundant mycorrhiza, the only stand to do so. Soil reaction in this layer was extremely acid (pH 4.5), almost 1.5 units lower than any other soil reaction tested. The abundance of mycorrhiza and the acidic surface horizon indicate that this particular soil may have escaped flooding, high water table conditions or other perturbations which typified the developmental history of all the other soils. An excessively stony loamy sand Bg horizon (80 to 90 % by volume) characterized the surface mineral horizon. The rounded to sub-angular stones were up to 25 cm in diameter. A mildly alkaline soil reaction of 7.7 was in sharp contrast to the LFH horizon.

Soil Climate

The upper terrace of the West Terrace Control was significantly cooler and wetter ($p < 0.05$) than either the lower terrace or the East Talus Control (Table 4.18). This terrace had a mean temperature of 5.1°C, while moisture averaged 170%. A significantly warmer and drier soil climate ($p < 0.05$) characterized the lower terrace, as its mean temperature and moisture values were 7.2°C and 53%, respectively. When the values for both terraces were combined, the West Terrace Control, had a relatively cool and moist soil climate. The average temperature was 6.1°C while moisture content was 105%.

Of the undisturbed controls, the East Talus soils were the warmest at 8.9°C ($p < 0.05$). Soil moisture at 81% was not statistically different from the West Side Undisturbed Control (both terraces), which averaged 105%. It was significantly ($p < 0.05$) drier than the upper terrace, however.

To summarize, soil climates of the Undisturbed Controls were classified as:

1) hygric and cool-- *Picea glauca/ Ledum groenlandicum/ Festuca altaica/ Hylocomium splendens* West Terrace Control (Upper Terrace);

2) sub-hygric and cool-- *Picea glauca/ Ledum groenlandicum/ Festuca altaica/ Hylocomium splendens* West Terrace Control (both terraces);

3) Mesic and moderately warm-- *Picea glauca/ Dryas integrifolia/ Carex scirpoidea/ Cladina mitis* East Side Talus Control; and *Picea glauca/ Ledum groenlandicum/ Festuca altaica/ Hylocomium splendens* -- West Terrace Control (Lower Terrace).

4.2 DISTURBANCES

4.2.1 Disturbance Regime Variables

CANOL No. 1 Project perturbations at milepost 40, Dodo Valley, N.W.T. were described and/or classified semi-qualitatively, according to four disturbance regime variables:

1) spatial extent;
2) terrain sensitivity;
3) intensity;
4) severity.

Spatial Extent

The spatial dimensions of each CANOL No. 1 Project disturbance were described in terms of length, width, area, perimeter, and perimeter to area ratio (Table 4.4). The road and bladed trails were linear disturbances which occupied relatively large areas (2550 to 5855 m^2. Lengths ranged from 425 m (Major Right-of-Way) to 704 m (Road), while mean maximum widths reached 8.8 m (Telephone Right-of-Way). Bladed Slope G was also a linear perturbation, but of smaller dimensions, as its area of 250 m^2 was at least ten times lower than the other linear disturbances. Regardless of actual area occupied, these disturbance types had moderately large perimeter:area values of 0.23 to 0.44, and, hence, may have had a greater tendency to resemble the surrounding vegetation (Bell et al. 1974).

The Borrow Pits and Bladed Slopes were, with the exception of Bladed Slope D, smaller surfaces than their linearly-shaped counterparts. Areas ranged from 523 to 1460 m^2. However, because these sites were more circular in shape, the perimeter to area ratios were considerably smaller (0.12 to 0.16).

Terrain Sensitivity

The two control sites, the East Control and the West Control, were classified according to Kurfurst's (1973) system (Appendix 1). Their values were 1.7 and 1.3 respectively, indicating that the former was more sensitive.

The Terrain Sensitivity rankings for each disturbance ranged from 1.0 on the Major Right-of-Way to 1.7 for all perturbations located on the East Control (Table 4.5).

Intensity

Table 4.4: Spatial Dimensions of the CANOL Disturbances

Milepost 40, Dodo Valley, N.W.T.

Disturbance	Length (m)	Width (m)	Area (m^2)	Perimeter (m)	Perimeter: Area Ratio
1. Road	704	7.3	5139.2	1442.60	0.28
2. Borrow Pit A	34*	26+	725.7	101.51	0.14
3. Borrow Pit B	27*	23+	522.9	84.46	0.16
4. Borrow Pit F	22*	30+	659.8	86.37	0.13
5a Bladed Slope D	80*	21+	1460.5	175.77	0.12
5b Bladed Slope G	50	5.0	250.0	110.00	0.44
6. Telephone R.O.W.	665	8.8	5855.5	1348.30	0.23
7. Minor R.O.W.	530	5.5	2915.0	1071.00	0.37
8. Major R.O.W.	425	6.0	2550.0	862.00	0.34

* Length parallel to the road.
+ Maximum distance from the road.

Table 4.5: Terrain Sensitivity Ratings for Controls and Disturbances

Milepost 40, Dodo Valley, N.W.T.

Location	Terrain Sensitivity Index[1]
Borrow Pits	1.7
Bladed Slopes	1.7
Road	1.5
Telephone Line Right-of-Way	1.3
Minor Right-of-Way	1.3
Major Right-of-Way	1.0

1. Modified from Kurfurst (1973).

A modified Heginbottom (1973) Model was used in order to assign intensity values for each perturbation (Appendix 2). The intensity of the CANOL disturbances ranged from 6 (shallow bulldozing associated with bladed trail development) to 10 (the most intensive class, which was attributed to road construction) (Table 4.5).

Road construction disturbances were considered the most intense, because the vegetation and soil profile was completely removed and the road surface was compacted. Although all plant material was destroyed, and the soil profile excavated to a greater depth than with the road, the magnitude of the borrow pit construction was considered less intense because compaction was limited to only a portion of the surface (i.e. the borrow pit floor) and the soil profiles near the borrow pit edges were only partially destroyed. It was classified as a 9.

The relative shallowness of the bulldozing on the bladed slopes, in comparison to the borrow pits, resulted in these surfaces being placed in intensity class 8.

Only a portion of the LFH and A mineral horizons were removed during bladed trail construction. As well, not all vegetation was destroyed, as some shrub species situated on the rights-of-way pre-dated 1942. The intensity of these disturbances was considered moderate (i.e. class 6).

Severity

Disturbance severity is related to intensity. This is not a direct cause-effect relationship, as Higginbottom (1973) implied, however. Other factors such as terrain sensitivity, seasonality, vegetation characteristics (e.g. age, physiognomic structure) also influence the severity that a disturbance of given intensity will have. For example, bladed trail construction on a tree-dominated system will undergo a greater degree of physiognomic structure simplification than will right-of-way development on a shrub-dominated site (Haag

Table 4.6: Intensity of CANOL Disturbances

Milepost 40, Dodo Valley, N.W.T.

Location	Disturbance Intensity[1]
Borrow Pit A	9
Borrow Pit B	9
Borrow Pit F	9
Bladed Slope D	8
Bladed Slope G	8
Road	10
Telephone Line Right-of-Way	6
Minor Right-of-Way	6
Major Right-of-Way	6

[1] Modified from Heginbottom (1973).

1974).

Disturbance severity was quantified through calculation of the degree of:

1) physiognomic structure simplification and

2) microtopographical change

4.2.2 Vegetation

Plant community development on the CANOL disturbance sites ranged from poor to good. Most sites were characterized by a sparse or absent tree stratum. Non-vascular plants were only important on the bladed trails. Shrubs tended to proliferate on all disturbances, with some species such as *Betula glandulosa, Ledum groenlandicum, Dryas drummondii, D. integrifolia* and *Salix* spp., frequently exceeding control values. All species identified on the disturbances were also present in the two undisturbed controls. Complete floras are listed in Appendix 6.

Borrow Pit A

Borrow Pit A was dominated by shrub and graminoid species as they accounted for over 87% of the plant cover and almost half of the 53 species (Table 4.8). Trees were rare. *Picea glauca* and *Picea mariana* occurred in 25% of the plots, had a combined cover of 0.2%, and a density of only 40 stems ha^{-2}.

All three shrub strata contained a relatively large number of abundant species. The tall shrub stratum was dominated by *Salix alaxensis* and *S. arbusculoides* (Table 4.8). *Potentilla fruticosa* and *Betula glandulosa,* which had extensive covers on all sites, composed 60% of the medium shrub cover in Borrow Pit A. Dwarf Shrubs were the most extensive. *Dryas integrifolia* appeared to be well-adapted to the borrow pit growth conditions as its 7.9% cover was the highest among all species. *Arctostaphylos uva-ursi* and *A. rubra* also contributed to a widespread mat of surface vegetation. All three taxa were abundant in adjoining East Talus Control vegetation.

Table 4.7: Shrub Destruction and Microtopographical Change on Controls and CANOL No. 1 Project Disturbances

Milepost 40, Dodo Valley, N.W.T.

Location	Shrub Destr'n[1] (%)	Micro.[2] Change
East Talus Control	0	0
West Terrace Control	0	0
Borrow Pit A	100	10
Borrow Pit B	100	22
Borrow Pit F	100	30
Bladed Slope D	100	12
Bladed Slope G	100	27
Road	100	43
Telephone Line R.O.W.	35	18
Minor R.O.W.	73	42
Major R.O.W.	19	32

1. Abbreviation for "Destruction."
2. Abbreviation for "Microtopographical."

Table 4.8: Borrow Pit A, Dodo Valley, N.W.T.

Major Species Per Stratum

STRATUM	SPECIES	% FREQUENCY	% COVER
TREE (over 2m)	*Picea mariana*	12.5	0.1
	Picea glauca	12.5	0.1
TALL SHRUB (over 1m)	*Salix alaxensis*	75.0	5.9
	Salix arbusculoides	75.0	3.3
MEDIUM SHRUB (10cm - 1m)	*Potentilla fruticosa*	100.0	2.4
	Betula glandulosa	87.5	2.3
DWARF SHRUB (0 - 9cm)	*Dryas integrifolia*	100.0	7.9
	Arctostaphylos uva-ursi	62.5	3.0
FORB Broad leaf herbaceous*	*Hedysarum alpinum*	50.0	0.6
	Anemone parviflora	50.0	0.3
Graminoid	*Carex scirpoidea*	87.5	4.9
	Elymus innovatus	87.5	1.6
	Calamagrostis neglecta	37.5	0.3
NON-VASCULAR Bryophyte	*Drepanocladus uncinatus*	62.5	2.0
	Rhytidium rugosum	50.0	1.5
	Bryum spp.	25.0	1.0
Lichen	None.	N/A	N/A

* Includes pteridophyte species.

The species-rich forb stratum (R = 18) had a total cover of only 1.7% and was dominated by a legume, ***Hedysarum alpinum***. Graminoids, however, with a total cover of 7%, were abundant.***Carex scirpoidea*** and ***Elymus innovatus*** were the major species.

Lichens were absent in Borrow Pit A, while the bryophytes were sparse with a cover of 5.2%. ***Drepanocladus uncinatus*, *Rhytidium rugosum*,** and ***Bryum*** spp., all typical of rocky habitats, were the major species.

Borrow Pit B

Borrow Pit B had the most species-rich (R = 69) and abundant (cover = 66%) vegetation of the three borrow pits (Appendix 6). There were no trees, although ***Picea glauca*** and ***Populus balsamifera*** were common in the shrub layers (Table 4.9). ***Picea mariana*** and ***Larix laricina*** were present but rare.

Of the vegetation cover, 80% occurred in the shrub strata. As was the case for most sites, only one or two species dominated each layer. ***Alnus crispa*** and ***Salix alaxensis*** combined to produce an extensive tall shrub stratum with a mean cover of 26%. The medium shrub layer was less well-developed (cover = 6.3%). Its principal species were ***Betula glandulosa*** and ***Potentilla fruticosa***. ***Dryas integrifolia*** was clearly the most abundant species in the dwarf shrub stratum, and for the community as a whole (Table 4.9). ***Salix myrtillifolia*** was also important in this layer. The prominent road-colonizing species, ***Dryas drummondii*,** however, had a cover of only 0.01%, and, presumably was unadapted to the unstable and unconsolidated stony borrow pit walls, or unable to cope with the shade of the well-developed tall and medium shrub layers.

Hedysarum alpinum and ***Equisetum arvense*** dominated the extensive forb layer (Table 4.9). The 26 species accounted for over 7% of the vegetation cover.

Graminoids were also extensive, but their overall cover was moderate at 3.0%. ***Carex scirpoidea*** and ***Elymus innovatus*,** both of which can tolerate a wide range of growth conditions, were the major species.

Table 4.9: Borrow Pit B, Dodo Valley, N.W.T.

Major Species Per Stratum

STRATUM	SPECIES	% FREQUENCY	% COVER
TREE (over 2m)	None.	N/A	N/A
TALL SHRUB (over 1m)	*Alnus crispa*	77.8	11.6
	Salix alaxensis	88.9	9.8
MEDIUM SHRUB (10cm.- 1m)	*Betula glandulosa*	88.9	3.1
	Potentilla fruticosa	100.0	1.5
DWARF SHRUB (0 - 9cm)	*Dryas integrifolia*	100.0	16.8
	Salix myrtillifolia	44.4	2.3
FORB Broad leaf herbaceous*	*Hedysarum alpinum*	55.6	0.8
	Equisetum arvense	55.6	0.5
Graminoid	*Carex scirpoidea*	77.8	1.8
	Elymus innovatus	66.7	0.7
	Carex membranacea	11.1	0.2
NON-VASCULAR Bryophyte	*Drepanocladus uncinatus*	66.7	2.1
	Rhytidium rugosum	77.8	1.7
	Thuidium abietinum	44.4	0.8
Lichen	*Cladina verticillata*	11.1	0.001

* Includes pteridophyte species.

The non-vascular layer was typified by an almost complete absence of lichens (Appendix 6). Bryophytes were also sparse. Three calciphytes, ***Drepanocladus uncinatus*, *Rhytidium rugosum*** and ***Thuidium abietinum*** were the principal species on the calcareous substrate.

Borrow Pit F

In spite of low overall abundance Borrow Pit F vegetation was considered well-developed (Table 4.10). Borrow Pit F contained 56 species, each stratum was moderately to extensively distributed, and tree density reached 130 stems ha^2. In addition, the non-vascular layers were abundant and accounted for over 25% of the vegetative cover. Trees were relatively common with a 57% frequency and a 3.9% cover. ***Populus balsamifera*, *Picea glauca*** and ***Larix laricina*** were all present.

Maximum ages (Appendix 6) indicated that some trees were introduced to the pit by "rafting" from above the headwall. A ***Picea glauca*** specimen was 115 years old, while one ***Larix laricina*** exceeded 60 years. This form of borrow pit revegetation i.e. rafting had undoubtedly assisted tree establishment.

Both tall and medium shrub strata were well distributed, but moderately sparse (Table 4.10). ***Salix alaxensis*** was the major tall shrub species, followed by immature ***Populus balsamifera*** and ***Picea glauca***. As was the case for most sites, the principal medium shrubs were ***Betula glandulosa*** and ***Potentilla fruticosa*** .

Two evergreens, ***Dryas integrifolia*** and ***Arctostaphylos uva-ursi*,** accounted for three-quarters of the dwarf shrub stratum cover. In fact, seven of the eight species were evergreen with ***Salix myrtillifolia*** the lone exception.

Even though each growth form achieved 100% frequency, forb and graminoid covers were relatively low. ***Equisetum arvense*** and ***Hedysarum alpinum*** were the dominant forbs. Sedges accounted for 95% of the graminoid cover. The presence of ***Carex vaginata*** as the major species indicated that drainage on the borrow pit floor was poor. ***Carex scirpoidea*,** which also may inhabit wet areas, and ***Carex microglochin*** were the other important

Table 4.10: Borrow Pit F, Dodo Valley, N.W.T.

Major Species Per Stratum

STRATUM	SPECIES	% FREQUENCY	% COVER
TREE (over 2m)	*Larix laricina*	14.3	0.5
	Picea glauca	57.1	0.4
	Populus balsamifera	28.5	0.2
TALL SHRUB (over 1m)	*Salix alaxensis*	100.0	3.9
	Populus balsamifera	33.0	0.6
	Picea glauca	33.0	0.4
MEDIUM SHRUB (10cm - 1m)	*Betula glandulosa*	85.7	2.3
	Potentilla fruticosa	100.0	0.7
DWARF SHRUB (0 - 9cm)	*Dryas integrifolia*	100.0	6.3
	Arctostaphylos urv-ursi	42.9	1.8
FORB Broad leaf herbaceous*	*Equisetum arvense*	14.2	0.3
	Hedysarum alpinum	42.9	0.2
Graminoid	*Carex vaginata*	42.9	0.6
	Carex microglochin	57.1	0.4
	Carex scirpoidea	42.9	0.3
NON-VASCULAR Bryophyte	*Drepanocladus uncinatus*	57.1	6.6
	Hypnum bambergii	28.6	0.1
	Thuidium abietinum	42.9	0.1
Lichen	*Cladina mitis*	14.3	1.1
	Cladina stellaris	14.3	0.4

* Includes pteridophyte species.

graminoids (Table 4.10).

Seven lichen species identified in the borrow pit contributed over 5% of the plant cover total. *Cladina mitis* and *C. alpestris* were the major taxa. Their low frequencies suggest that their presence may be attributed ,in part, to rafting.

Drepanocladus uncinatus was the most abundant and well-distributed non-vascular species in the borrow pit (Table 4.10 and Appendix 6), while all other bryophytes were rare.

Bladed Slope D

The vegetation on this bladed slope had only a moderate cover of 33.8%. It was composed of 51 vascular and 5 non-vascular plant species (Appendix 6). The community was poorly developed. There were no tree or lichen strata, and the moss, graminoid, and forb covers were relatively low. Development in the shrub strata was only moderately better (Table 4.11).

Populus balsamifera was the most abundant species in the tall shrub stratum, followed by *Salix alaxensis* and *Alnus crispa. Larix laricina* and *Picea glauca* were also present (Table 4.11). With the exception of *Picea glauca*, deciduous species dominated the medium shrub layer. Important taxa were *Betula glandulosa, Populus balsamifera,* and *Shepherdia canadensis.* In contrast, two-thirds of the dwarf shrub cover was evergreen. *Dryas integrifolia* and *D. drummondii* were dominant. The relatively high cover of *D. drummondii* (7.8%) appeared to be related to the openness of the overstory and the compacted nature of the soil surface.

Forbs were ubiquitous, but sparse. *Hedysarum alpinum* was the most abundant taxon, with a frequency of 63% and a cover of 0.9%. The graminoid layer was also sporadic with *Elymus innovatus* achieving the highest cover at only 0.3%.

While there were five bryophyte species, lichens were absent. Once again *Drepanocladus uncinatus* was the dominant non-vascular plant (Table 4.11).

Bladed Slope G

Table 4.11: Bladed Surface D, Dodo Valley, N.W.T.

Major Species Per Stratum

STRATUM	SPECIES	% FREQUENCY	% COVER
TREE (over 2m)	None.	N/A	N/A
TALL SHRUB (over 1m.)	*Populus balsamifera*	62.5	2.8
	Salix alaxensis	87.5	1.6
	Alnus crispa	12.5	0.4
MEDIUM SHRUB (10cm - 1m)	*Betula glandulosa*	62.5	2.4
	Populus balsamifera	50.0	1.3
	Picea glauca	87.5	1.0
	Shepherdia canadensis	25.0	0.8
DWARF SHRUB (0 - 9cm)	*Dryas integrifolia*	75.0	8.6
	Dryas drummondii	75.0	7.8
FORB Broad leaf herbaceous*	*Hedysarum alpinum*	62.5	0.9
	Habenaria oppositifolia	12.5	0.4
Graminoid	*Elymus innovatus*	37.5	0.3
	Carex vaginata	12.5	0.3
	Festuca altaica	25.0	0.1
NON-VASCULAR Bryophyte	*Drepanocladus uncinatus*	50.0	0.9
	Ditrichum flexicaule	25.0	0.1
Lichen	None.	N/A	N/A

* Includes pteridophyte species.

This linear disturbance was, botanically, the least developed site. Although a species richness of 56 was comparable with other communities, total cover was only 22.2%. In addition there was no tree stratum, and shrub density was relatively low at 18.2 stem m^{-2}. Even shrub cover was sparse, relative to other sites, at 15.8%.

Salix alaxensis and *Populus balsamifera* were the prominent tall shrubs in a well-distributed, but meager layer (Table 4.12). Medium shrubs were more common, but also sparse. *Betula glandulosa* and *Potentilla fruticosa* contributed about 50% of this layer's cover while *Picea mariana* and *Picea glauca* were scattered throughout this stratum.

Dwarf shrub species have tended to be the most successful colonizers of the CANOL disturbances. This bladed slope was no exception, as this growth form accounted for approximately 50% of the total cover. Evergreens dominated and constituted seven of the eight species. *Dryas integrifolia* and *D. drummondii* achieved the highest covers (Table 6.10). Two forb species, *Senecio lugens* and *Anemone parviflora* were well-distributed throughout this site but, typically, managed only low covers.

Carex scirpoidea, at 2.6% cover, was considered abundant on this disturbance but it exhibited a clumped distribution (Appendix 6). Other important graminoids in this moderately well-developed layer were *C. microglochin* and *C. vaginata*.

Although five lichens were identified, this layer had a cover of only 0.1%. Bryophytes were slightly more abundant, but were also scattered throughout the stand. *Rhytidium rugosum* and *Drepanocladus uncinatus* were the major taxa.

Road

The Road vegetation was typified by well-developed tall and dwarf shrub strata. All other layers exhibited moderate to poor development. A total of 27 trees: 22 *Populus balsamifera and 5 Picea glauca*, were counted for a density of 80 stem ha^{-1}. The presence of *P. glauca* in the tree layer and its high density of 3.46 stem m^{2} in the shrub strata indicated excellent tree regeneration, as this value exceeded that of controls.

Table 4.12: Bladed Surface G, Dodo Valley, N.W.T.

Major Species Per Stratum

STRATUM	SPECIES	% FREQUENCY	% COVER
TREE (over 2m)	*None.*	N/A	N/A
TALL SHRUB (over 1m)	*Salix alaxensis*	80.0	0.9
	Populus balsamifera	20.0	0.8
	Salix arbusculoides	60.0	0.2
	Salix glauca	20.0	0.2
MEDIUM SHRUB (10 cm - 1m)	*Betula glandulosa*	100.0	0.6
	Potentilla fruticosa	100.0	0.5
DWARF SHRUB (0 - 9cm)	*Dryas integrifolia*	100.0	8.0
	Dryas drummondii	80.0	2.2
FORB Broad leaf herbaceous*	*Senecio lugens*	80.0	0.1
	Anemone parviflora	100.0	0.1
Graminoid	*Carex scirpoidea*	40.0	2.6
	Carex microglochin	40.0	0.7
	Carex vaginata	40.0	0.6
NON-VASCULAR Bryophyte	*Rhytidium rugosum*	25.0	0.8
	Drepanocladus uncinatus	40.0	0.4
Lichen	*Dactylina arctica*	20.0	0.1
	Cetraria nivalis	20.0	0.02
	Cladonia verticillata	20.0	0.02

* Includes pteridophyte species.

The tall shrub stratum was composed of six species, had a 77% frequency, and a cover of 11.6%, thus accounting for 17% of the total vegetation. *Populus balsamifera* and *Salix alaxensis* dominated this layer, and combined to produce 82% of the tall shrub cover (Table 4.13).

Twelve species occupied the medium shrub layer, only four less than on the adjacent East and West Controls. The abundance of this stratum was far less substantial, however, as mean cover was just over 4%. *Salix brachycarpa*, a common sand dune and gravel bar species, and *Potentilla fruticosa* were the most abundant taxa (Table 4.13).

The dwarf shrub stratum was again the best developed layer. *Dryas drummondii*, a shade-intolerant gravel bar species was ubiquitous on the road, constituting almost 63% of the plant cover. *D. integrifolia*, was also an important species.

The species rich (R=34) and extensive (frequency = 93%) forb stratum had a cover of only 2.6%. *Equisetum arvense, Epilobium latifolium*, and *Oxytropis campestris* were key forb species, however, the graminoid, lichen, and bryophyte layers were sparse as no species achieved a cover greater than 1%.

Telephone Line Right-of-Way

Vegetation on this bladed trail was abundant, as mean plant cover was 108%. Physiognomically, the Telephone Line Right-of-Way had well-developed medium and dwarf shrub, graminoid, lichen and bryophyte layers. All five were relatively species-rich, had high frequencies (76% or greater), and cover values. Stem densities of 74.6/m^2 for the erect shrubs also indicated a well-developed shrub stratum. *Picea glauca* and *Larix laricina* were the major tree species in a moderately well-developed tree layer (Table 4.14 and Figure 4.5).

Tall shrubs were sparsely distributed, contributed only 5% of the total cover and formed the most species-poor understory stratum (R=6). *Salix alaxensis* was the dominant shrub in this layer (Table 4.14).

Three evergreen and eight deciduous species composed the medium shrub layer. Both spruce tree species were also present, but had low covers: *Picea glauca* at 0.7% and *P.*

Table 4.13: Road-- Dodo Valley, N.W.T.

Major Species Per Stratum

STRATUM	SPECIES	% FREQUENCY	% COVER
TREE (over 2m)	*Populus balsamifera*	17.1	0.6
	Picea glauca	5.7	0.1
TALL SHRUB (over 1m)	*Populus balsamifera*	97.1	5.5
	Salix alaxensis	60.0	4.0
	Alnus crispa	17.1	1.8
MEDIUM SHRUB (10 cm - 1m)	*Salix brachycarpa*	45.7	1.7
	Potentilla fruticosa	57.1	0.8
DWARF SHRUB (0 - 9cm)	*Dryas drummondii*	94.3	42.9
	Dryas integrifolia	65.7	4.5
FORB Broad leaf herbaceous*	*Equisetum arvense*	28.6	1.2
	Epilobium latifolium	34.3	0.6
	Oxytropis campestris	2.9	0.3
Graminoid	*Carex microglochin*	28.6	0.1
	Calamagrostis purpurascens	2.9	0.1
NON-VASCULAR Bryophyte	*Rhytidium rugosum*	14.3	0.2
	Thuidium abietinum	17.1	0.1
Lichen	*Cetraria nivalis*	2.9	0.0003

* Includes pteridophyte species.

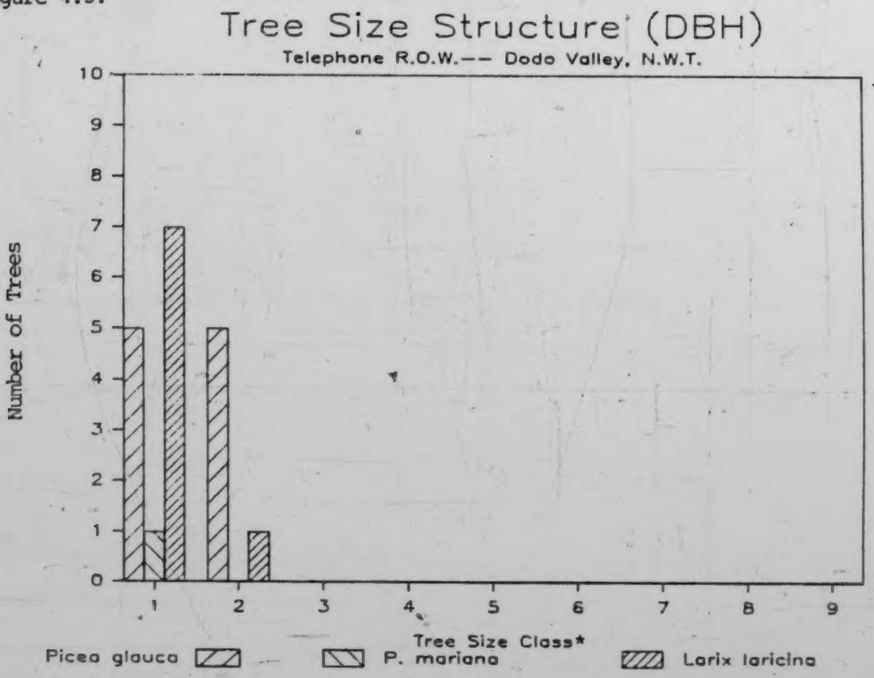
Table 4.14: Telephone Right-of-Way, Dodo Valley, N.W.T.

Major Species Per Stratum

STRATUM	SPECIES	% FREQUENCY	% COVER
TREE (over 2m)	*Picea glauca*	40.0	1.6
	Larix laricina	12.0	0.8
	Picea mariana	8.0	0.2
TALL SHRUB (over 1m)	*Salix alaxensis*	28.0	4.0
	Picea glauca	52.0	1.0
MEDIUM SHRUB (10cm - 1m)	*Betula glandulosa*	96.0	7.0
	Ledum groenlandicum	84.0	2.8
	Vaccinium uliginosum	96.0	2.2
	Potentilla fruticosa	92.0	2.1
DWARF SHRUB (0 - 9cm)	*Salix myrtillifolia*	84.0	3.6
	Dryas integrifolia	72.0	3.0
	Arctostaphylos rubra	92.0	2.8
	Empetrum nigrum	80.0	1.0
FORB Broad leaf herbaceous*	*Equisetum arvense*	44.0	0.7
	Saussurea angustifolia	56.0	0.6
	Equisetum scirpoides	64.0	0.3
Graminoid	*Carex vaginata*	72.0	2.6
	Festuca altaica	84.0	2.2
	Carex scirpoidea	80.0	2.2
NON-VASCULAR Bryophyte	*Hylocomium splendens*	68.0	24.32
	Pleurozium schreberi	72.0	10.1
	Rhytidium rugosum	84.0	9.1
Lichen	*Cladina mitis*	64.0	8.6
	Cladonia gracilis	32.0	1.3
	Peltigera aphthosa	40.0	0.3

* Includes pteridophyte species.

Figure 4.5:



*

Class:	1	2	3	4	5	6	7	8	9
Range (cm):	1-3.9	4-6.9	7-9.9	10-12.9	13-15.9	16-18.9	19-21.9	22-24.9	25-27.9

mariana at 0.03%. Due to the relative openness of the canopy it was not surprising that three of the four most abundant species were deciduous: *Betula glandulosa, Vaccinium uliginosum,* and *Potentilla fruticosa.*

The dwarf shrub stratum was species-rich (R=13). *Salix myrtillifolia,* a deciduous species, was the most common, followed by *Dryas integrifolia, Arctostaphylos rubra* and *Empetrum nigrum* (Table 4.14).

As was the case for most of the communities, forbs contributed the greatest number of species, but had low covers. Pteridophytes were the most prominent growth form, as *Equisetum arvense* and *E. scirpoides* combined for a mean cover of almost 1.00%.

The common graminoids were dominated by *Carex scirpoidea, Festuca altaica,* and *Carex vaginata. Cladina mitis* was clearly the most abundant lichen, contributing 80% of the total cover. *Cladonia gracilis* and *Peltigera apthosa* were also important taxa. Frequency was 100% while cover contributed over 45% of the vegetation total.

Hylocomium splendens and *Pleurozium schreberi* dominated the extensive bryophyte layer (Table 4.14). Frequency was 100% while cover contributed over 45% of the vegetation total.

Minor Right-of-Way

The medium shrub, dwarf shrub and bryophyte layers of the Minor Right-of-Way had 11, 10, and 12 species, respectively, maintained a 100% frequency, and had high covers. Forbs, graminoids and lichens were less abundant, but also species-rich and common. A total mean cover of 85% indicated that species abundances were, on average, over 20% lower on this Right-of-Way than on the Telephone (Table 4.15). The majority of this disparity in cover between the two Bladed Trails was due to an almost 20% lower non-vascular plant cover on the Minor Right-of-Way. A greater amount of exposed mineral soil observed on the Minor Right-of-Way strongly suggested deeper blading during construction. This may account for its lower non-vascular cover.

Table 4.15: Minor Right-of-Way, Dodo Valley, N.W.T.

Major Species Per Stratum

STRATUM	SPECIES	% FREQUENCY	% COVER
TREE (over 2m)	*Picea glauca*	35.0	1.0
	Larix laricina	15.0	0.4
	Picea mariana	10.0	0.2
TALL SHRUB (over 1m)	*Alnus crispa*	35.0	1.5
	Salix arbusculoides	40.0	0.6
MEDIUM SHRUB (10cm - 1m)	*Betula glandulosa*	95.0	8.1
	Potentilla fruticosa	95.0	2.7
	Ledum groenlandicum	100.0	2.2
	Vaccinium uliginosum	95.0	1.1
DWARF SHRUB (0 - 9cm)	*Salix myrtillifolia*	80.0	3.2
	Dryas integrifolia	90.0	2.9
	Salix reticulata	65.0	1.2
	Arctostaphylos rubra	75.0	1.2
FORB Broad leaf herbaceous*	*Equisetum arvense*	45.0	3.2
	Saussurea angustifolia	40.0	0.2
	Parnassia palustris	85.0	0.2
Graminoid	*Carex scirpoidea*	90.0	3.1
	Festuca altaica	80.0	1.7
	Carex vaginata	80.0	1.4
NON-VASCULAR Bryophyte	*Bylocomium splendens*	35.0	11.5
	Pleurozium schreberi	75.0	10.1
	Rhytidium rugosum	90.0	4.3
Lichen	*Cladina mitis*	60.0	6.6
	Cladonia gracilis	55.0	0.5
	Peltigera aphthosa	30.0	0.5

* Includes pteridophyte species.

Although all three tree species had colonized the Minor Right-of-Way they were relatively rare (Figure 4.6). *Picea glauca*, with ten individuals, had the highest stem density, followed by *Larix laricina* and *Picea mariana* with nine and two, respectively. Seven of the nine *Larix laricina* trees were found in one quadrat and, consequently, had a much lower frequency at 10% than *Picea glauca* (Figure 4.6).

Tall shrubs were also sparse. The major species were *Alnus crispa*, and *Salix arbusculoides*, while *Picea glauca*, *P. mariana* and *Larix laricina* were also present (Table 4.15).

The medium shrub layer was the best developed vascular plant stratum. The four dominant species were identical with those of the other two bladed trails and the West Terrace Control: *Betula glandulosa*, *Potentilla fruticosa*, *Ledum groenlandicum*, and *Vaccinium uliginosum*. *Betula glandulosa* accounted for almost half of the total cover of this layer. The presence of *Picea glauca* and *P. mariana* in this stratum once again indicated successful regeneration of tree species.

Salix myrtillifolia, *Dryas integrifolia* and *Arctostaphylous rubra* dominated the dwarf shrub layer of this and the other two Bladed Trails and West Control.

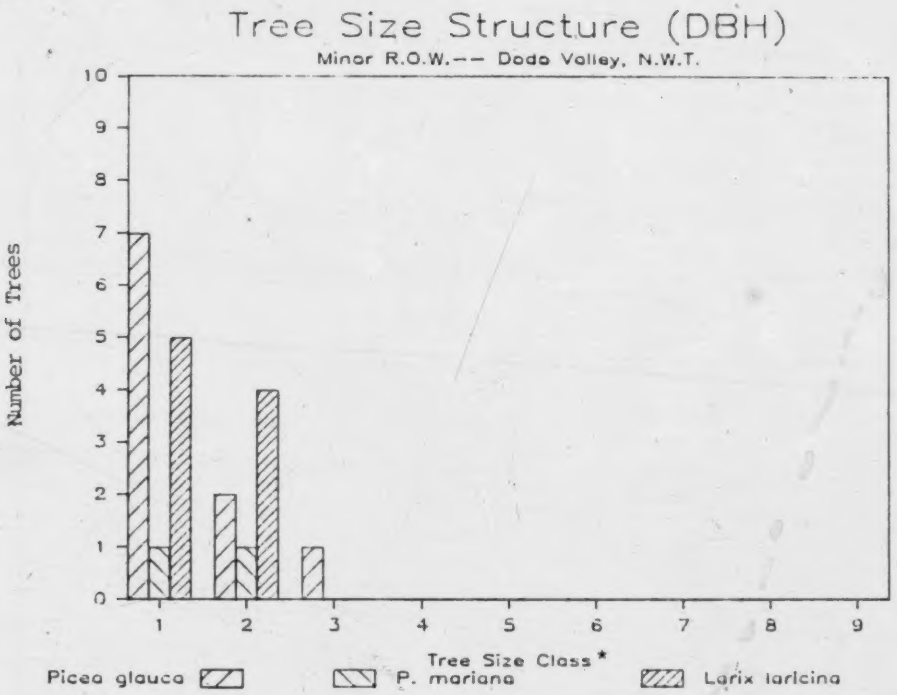
The sparse but rich forb layer (R = 33) was dominated by *Equisetum arvense*, *Saussurea angustifolium* and *Parnassia palustris*. Graminoids, particularly the sedges, were moderately abundant and well-distributed. *Carex scirpoidea*, *Festuca altaica* and *Carex vaginata* were the major species.

The lichen stratum was dominated by a single taxon, *Cladina mitis*. Its cover was 12.5 times greater than that of any other lichen on the Minor Right-of-Way. Dominance amongst the bryophytes was shared by several feathermoss species: *Hylocomium splendens*, *Pleurozium schreberi* and *Rhytidium rugosum* (Table 4.15).

Major Right-of-Way

Vegetation in the Major Right-of-Way was moderately abundant (cover = 79%) and species rich (R = 80). Physiognomically, this disturbance was similar to the other bladed trails,

Figure 4.6:



*

Class:	1	2	3	4	5	6	7	8	9
Range (cm):	1-3.9	4-6.9	7-9.9	10-12.9	13-15.9	16-18.9	19-21.9	22-24.9	25-27.9

with well-developed medium shrub, dwarf shrub and non-vascular plant layers. Differences included a proportionately more abundant graminoid stratum and the almost complete absence of a tree layer.

Only one species, *Picea glauca*, was identified in the tree stratum. It had a low frequency (6.6%) and cover (Table 4.16). This layer's sparseness was exemplified by the fact that no trees were rooted in any surveyed quadrat (i.e. stem density was zero).

Five tall shrub species were located on the Major Right-of-Way, but typically frequency and cover were low. *Salix alaxensis* and *S. glauca* were the two major taxa. *Picea glauca* was rare, indicating limited regeneration.

The medium shrub layer (r= 10) had a cover of 15% and was the best developed stratum. *Vaccinium uliginosum* was more abundant here than anywhere else in the study area. *Betula glandulosa, Ledum groenlandicum* and *Potentilla fruticosa* were also important species.

Dwarf shrubs were dominated by *Arctostaphylos rubra, Linnaea borealis* and *Dryas integrifolia.* This layer formed a uniform mat throughout the bladed trail.

The forb layer which had 27 species and a cover of 4%, was dominated by two nitrogen-fixing legumes: *Hedysarum boreale* and *H. alpinum. Carex membranacea,* exhibited a clumped distribution but comprised 57% of this layer's cover total. Other important species were *Elymus innovatus* and *Festuca altaica* (Table 4.16).

Cladina mitis was the dominant taxon in the species poor (R=8) and patchy lichen stratum as its cover of 4.2% was low in comparison to the Telephone and Minor Rights-of-Way (8.60 and 6.61%, respectively). *Cladonia stellaris* and *Cladonia gracilis* were also relatively common.

The bryophyte layer was better developed. With the exception of *Thuidium abietinum, Pleurozium schreberi*, and *Rhytidium rugosum,* most species were patchy. *Hylocomium splendens* was also infrequently encountered achieving a cover of only 3.0%, far below its abundance on the other bladed trails and control sites (Tables 4.1 to 4.2 and 4.14 to 4.16).

Table 4.16: Major Right-of-Way, Dodo Valley, N.W.T.

Major Species Per Stratum

STRATUM	SPECIES	% FREQUENCY	% COVER
TREE (over 2m)	*Picea glauca*	6.6	0.1
TALL SHRUB (over 1m)	*Salix alaxensis*	33.3	0.5
	Salix glauca	13.3	0.4
MEDIUM SHRUB (10cm - 1m)	*Vaccinium uliginosum*	80.0	5.0
	Betula glandulosa	67.0	4.8
	Ledum groenlandicum	87.0	2.3
	Potentilla fruticosa	80.0	1.3
DWARF SHRUB (0 - 9cm)	*Arctostaphylos rubra*	80.0	2.9
	Linnaea borealis	60.0	2.8
	Dryas integrifolia	73.0	2.3
	Salix myrtillifolia	60.0	1.9
FORB Broad leaf herbaceous*	*Hedysarum boreale*	40.0	1.1
	Hedysarum alpinum	67.0	0.7
	Equisetum arvense	47.0	0.5
Graminoid	*Carex membranacea*	20.0	9.2
	Elymus innovatus	80.0	2.4
	Festuca altaica	87.0	1.7
NON-VASCULAR Bryophyte	*Drepanocladus uncinatus*	20.0	11.0
	Pleurozium schreberi	60.0	5.5
	Hylocomium splendens	20.0	3.0
Lichen	*Cladina mitis*	33.0	4.2
	Cladina stellaris	13.0	1.5
	Cladonia gracilis	40.0	0.5

* Includes pteridophyte species.

4.2.3 Important Plant Species on Disturbances

Numerous plant species exhibited moderate (2 to 5%) to relatively high (>>5%) covers on the disturbances (Table 4.17). These taxa not only demonstrated an ability to survive or colonize disturbances, but persist on them as well.

Two species achieved at least 2% cover on virtually all the disturbances: *Betula glandulosa* and *Dryas integrifolia.* All others appeared to be restricted to particular disturbances or disturbance types.

Dryas drummondii, Populus balsamifera, Salix alaxensis, Betula glandulosa, Carex scirpoidea as well as *Dryas integrifolia* were the principal taxa on the Road and bladed slopes. These disturbances appeared to be colonized strictly by seed.

The three borrow pits contained more abundant species than the Road or bladed slopes, due in part to rafting. *Betula glandulosa, Salix alaxensis, Salix arbusculoides, Dryas integrifolia, Potentilla fruticosa,* and *Drepanocladus uncinatus* may, therefore, provide some reclamation utility if sod transplants are used.

Many of the common bladed trail species most probably survived the original perturbations. Common taxa were primarily non-vascular plants: *Hylocomium splendens, Pleurozium schreberi, Rhytidium rugosum, Drepanocladus uncinatus* and *Cladina mitis.* Important vascular plants included *Betula glandulosa, Salix myrtillifolia, Dryas integrifolia, Ledum groenlandicum,* and *Arctostaphylos rubra. Carex membranacea,* which was locally abundant on the Major Right-of-Way, and *Carex scirpoidea* on the Telephone and Minor Rights-of-Way, were the only sedges or graminoids which responded favourably to the bladed trail's conditions.

Table 4.17: Species Which Achieved Relatively High Abundances on CANOL No. 1 Project Disturbances (< 2%)

Milepost 40, Dodo Valley, N.W.T.

Species	Disturbances								
Vascular Plants	BP-A	BP-B	BP-F	BS-D	BS-G	Road	Tele.	Minor	Major
Alnus crispa	-	11.6	-	-	-	-	-	-	-
Arctostaphylos rubra	-	-	-	-	-	-	2.8	-	2.9
Betula glandulosa	2.3	3.1	2.4	2.4	-	-	7.0	8.1	4.9
Carex membranacea	-	-	-	-	-	-	-	-	9.2
Carex scirpoidea	4.9	-	-	-	2.6	-	2.2	3.1	-
Dryas drummondii	-	-	-	7.8	2.2	42.9	-	-	-
Dryas integrifolia	7.9	16.8	6.4	8.6	8.0	4.5	3.0	2.9	2.3
Ledum groenlandicum	-	-	-	-	-	-	2.8	2.2	2.3
Populus balsamifera	-	3.2	-	4.0	-	6.1	-	-	-
Potentilla fruticosa	2.4	-	-	-	-	-	2.1	2.7	-
Salix alaxensis	5.9	9.8	3.9	-	-	4.0	4.0	-	-
Salix myrtillifolia	-	2.3	-	-	-	-	3.6	3.2	-
Vaccinium uliginosum	-	-	-	-	-	-	2.2	-	5.1
Non- Vascular Plants									
Cladina mitis	-	-	-	-	-	-	8.6	6.6	4.2
Drepanocladus uncinatus	2.0	2.1	6.6	-	-	-	-	2.5	11.0
Hylocomium splendens	-	-	-	-	-	-	24.3	11.5	3.0
Pleurozium schreberi	-	-	-	-	-	-	10.1	10.1	5.5
Rhytidium rugosum	-	-	-	-	-	-	9.1	4.3	-

4.2.4 Soils

Soils of the CANOL disturbances were described and sampled in at least two locations. To avoid repetition the three Borrow Pit soils were described together. Sample profiles from each site are listed in Appendix 7.

Borrow Pits

Borrow pit soils were extremely heterogeneous, but were dominated by Orthic and Gleyed Regosols. Regosolic soils are well- and imperfectly-drained mineral soils, which have horizon development too weak to meet the requirements of any other order (CSSC 1970).

Regosols:

The well-drained Orthic Regosols were confined to the Borrow Pit walls. They were characterized by very gravelly loam (50 to 90% by volume), with silt-clay and sandy lenses. The gravel consisted of sub-angular to angular stones from 1 to 20 cm in diameter. An Ah horizon of up to 3 cm was discontinuously distributed through the Pit side walls. Imperfectly drained Gleyed Regosols characterized the floors of all 3 Borrow Pits. Faint mottling and very dark gray to dark gray-brown colours were typical of these gravelly, but relatively fine-textured, soils. Clay contents ranged from 40 to 75% in the surface horizons.

Eutric Brunisol:

Profile development which met the requirements of the Brunisolic order (i.e. Bm and Ah horizons), were observed near the edges of the Pits. The limited presence of Brunisols at the periphery of the Pits indicated either incomplete destruction of the soil by gravel extraction activities, or post-disturbance erosion from upslope locations. The latter process would have contributed to the observed soil heterogeneity.

Bladed Slope D

While soils in the Borrow Pits were spatially heterogeneous, those of Bladed Slope D, and presumably Bladed Slope G, were uniform across the slope. Bladed Slope D's soil was classified as Eutric Brunisol, the same type that dominated the adjacent East Talus Control. Although the LFH and A horizons had been removed during the CANOL disturbance, a large portion of the B horizon (8 to 11 cm) remained.

Soil reaction at the surface and with depth was moderately alkaline (8.0 to 8.1). Texture was characterized by excessively stony loam and sandy loam material. Clasts which ranged in size from 1 to 25 cm, were rounded to angular in form.

Road

The Road substrate consisted of compacted coarse-textured gravelly material extracted from the Borrow Pits, and buried pockets of organic soil, which had been incorporated into the Road fill. Pre-disturbance soils were essentially eliminated during Road construction, either through burial or excavation. Due to the youthfulness of the substrate (40 years), and the lack of horizonation, the Road soils were classified as Regosols. Although Orthic Regosols predominated, Cumulic Regosols were also present, and were defined on the basis of buried LFH horizons (CSSC 1977).

Soil reaction was mildly alkaline, with pH's ranging from 7.5 to 8.1. Rounded to sub-angular pebbles and boulders from 1 cm to 50 cm in diameter composed 80 to 90% of the substrate, with the other 10 to 20% characterized by sandy and sandy-loam soils. Although organic matter in the surface horizon did not exceed 2.5%, intrusions of F-H and Ah material, were present at depths from 20 to 50 cm (Table 6.24). The buried organic horizons averaged 36% and 5% organic matter, respectively.

Telephone Right-of-Way

The north-south oriented Telephone Line Right-of-Way was dominated by Orthic Gleysols. Eutric Brunisols occurred in the northern portion of Stand C only.

Eutric Brunisol:

The Eutric Brunisol soil had a moderately thick (22 to 33 cm) LFH horizon overlying a sandy loam Bm, and an excessively stony Bm_2 horizon. Soil reaction was neutral at pH 6.6 near the surface, and increased to mildly alkaline (7.6) in the Bm horizon.

Orthic Gleysol:

Common, coarse and distinct mottles characterized the Bg horizon of the Orthic Gleysols. Soil colours of dark gray brown to very dark gray, and chromas of one also indicated reducing conditions. The LFH horizon approached 40 cm in thickness at the north end of this soil type, but was virtually absent at the south end. Angular to sub-angular, one to ten cm diameter stones were present in the Bg horizon, but occupied as much as 75%, by volume, of the Cg horizon. Soil reaction was slightly acid (6.1) in the organic layers, but was moderately alkaline in the C horizon. Where the organic matter layer was absent, the B horizons were more alkaline (8.0).

Minor Right-of-Way

The Minor Right-of-Way was located on the upper terrace and, therefore, crossed the same soil type as much of the Telephone Line Right-of-Way (i.e. Orthic Gleysols).

No mottling was observed but a very dark gray colour and a chroma of 1 in the clay loam Bg horizon indicated the presence of gleying. Depth of the organic horizon varied from 6 cm in Stand C to 23 cm in Stand E. This variability was most probably due to irregular blading along the trail or to an irregular relict microtopography. Compared to the Undisturbed Controls, the percentage of exposed mineral soil was higher on this Right-of-Way (5% versus 9%). This indicates that, unlike the Telephone Right-of-Way blading disturbed or removed the LFH horizons of the Minor Right-of-Way.

Soil structure was weakly granular, although clay lenses had medium sub-angular forms. The B-C horizon was excessively stony, with sub-angular stones to rounded pebbles occupying 90% of the soil by volume. Soil reaction was neutral at the surface (6.6 to 7.2), and mildly to moderately alkaline in the C horizon (7.5 to 7.7).

Major Right-of-Way

This bladed trail was located on the lower alluvial terrace of the West Terrace Control. Dominant soil attributes for much of the right-of-way were buried L-H and Ah horizons. These soils were classified as Cumulic Regosols.

Stoniness, a feature which characterized the surface or near-surface mineral horizons of most of the other soils, was present at a depth of 12 cm in Stand HA of the Major Right-of-Way. This horizon was buried under increasingly thicker layers of FH, Ah and sandy loam and loam material towards the west, where the rounded to sub-angular 1 to 8 cm diameter stones were located at a 40 cm depth in Stand HC.

The Cumulic Regosols exhibited a weak, granular structure. Surface reaction was moderately alkaline (pH 7.8 to 8.0), and did not change with depth. Exceptions in this regard were at buried, but relatively thin (1 to 4 cm) organic horizons, which had pH values 0.5 units lower. Organic matter at the surface was less than 4% and on average, decreased with depth. Buried organic horizons had percent organic matter values that ranged from 6.7 to 60.5 %.

Soil Moisture and Soil Temperature

Soil moisture and temperature (i.e. "soil climate") were measured periodically at 10 cm depth in each stand from June 30 through August 30, 1983. Each stand's values were compiled and allocated to the appropriate disturbance or control category.

Soil temperatures at 10 cm. depth on the CANOL disturbances had considerable between-site ranges in value, and all were slightly to substantially warmer than adjacent controls (Table 4.18). Soil temperatures ranged from 6.8°C on the Telephone Line Right-of-Way, to 13.8°C on the Bladed Slopes. Soil moisture values displayed an even greater range. The Bladed Slopes, Borrow Pits, and Road all averaged between 10% and 11% moisture, while the Minor Right-of-Way was over 160%. Disturbances of high intensity (8 to 10, i.e. Road, Borrow Pits, and Bladed Slopes) were significantly ($p < 0.05$) warmer and drier than controls. Soil climates on the Bladed Trails, which were disturbances of moderate intensity (class 6), were warmer but not significantly ($p >> 0.05$) drier than controls.

Road, Bladed Slopes and Borrow Pits

Borrow Pits and Bladed Slope temperatures were on average 3.1°C and 4.9°C warmer than adjacent Undisturbed Control soils of the East Talus Control. Soil moisture was significantly ($p < 0.05$) lower, as it was 70% lower than the same control.

The Road had a similar soil climate to the Bladed Slopes and Borrow Pits. This perturbation bisected the East Talus and the Upper Terrace portion of the West Terrace Controls. The Road's average soil temperature of 13°C, was 4.1°C and 7.9°C warmer than the two respective controls. Soil moisture was less than 11%, significantly lower than the East and West Undisturbed controls.

Table 4.18: Soil Moisture and Temperatures at 10 cm. Depth for Undisturbed Controls and Disturbances

Milepost 40, Dodo Valley, N.W.T.

Site	Soil Temperature (°C)			SOIL MOISTURE (%)		
	Mean	Range	n	Mean	Range	n
East Undisturbed Control	8.9 ± 1.1^{a2}	4 - 14	36	81 ± 22^{adf}	9 - 201	28
West Undisturbed Control	6.1 ± 0.7^{d}	1.4 - 13.2	55	105 ± 25^{a}	10 - 341	51
- Upper Terrace	5.1 ± 0.6	2.8 - 8.7	27	169.5 ± 39^{c}	20 - 341	23
- Lower Terrace	7.2 ± 1.2^{eg}	1.4 - 13.2	28	53 ± 16^{af}	10 - 147	28
Borrow Pits	12.0 ± 0.8^{b}	9 - 16	26	10.1 ± 1.3^{b}	4.7 - 14.9	25
Bladed Slopes	13.8 ± 1.9^{b}	9.7 - 17	12	10.1 ± 4.2^{b}	2.8 - 14.9	8
Road	13.0 ± 0.5^{b}	10.3 - 18	51	10.8 ± 1.9^{b}	4.8 - 26.7	32
Telephone Right-of-Way	6.8 ± 0.9^{de}	3 - 10	26	153.6 ± 48^{c}	15 - 318	20
Minor Right-of-Way	9.1 ± 1.4^{ag}	4 - 13.9	26	161 ± 85^{cde}	16 - 393	14
Major Right-of-Way	10.5 ± 0.8	9.2 - 12.1	10	45 ± 21^{ef}	6.4 - 95	12

1. Values are means ± 95% confidence limits.

2. Common letters indicate means that are not significantly different.

Bladed Trails

The Telephone Line Right-of-Way at 6.8 °C, was significantly ($p < 0.05$) warmer than the Undisturbed Upper Terrace soils at 10 cm. depth. This value for the Bladed Trail was statistically the same as the combined West Terrace Control temperature index value of 6.1 °C. It was, however, significantly ($p < 0.05$) cooler than the East Talus Control (Table 4.18). In addition, the Telephone Line Right-of-Way was slightly, but not significantly ($p < 0.05$), drier than Upper Terrace soils.

The soil climate of the Minor Right-of-Way was significantly warmer than that of the Upper Terrace and Telephone Line at 10 cm. depth. Its mean value of 9.1°C was statistically not different from the Lower Terrace at 7.2°C or the East Side Undisturbed Control (8.9 °C). The Minor Right-of-Way was the wettest of the disturbances, with an average moisture content of 161%. This value was comparable with those of the Upper Terrace and Telephone Line. In spite of being substantially wetter than the East Talus Control (81%) and the Major Right-of-Way (45%), there was no significant ($p < 0.05$) difference. This may be attributable to the small sample size ($n = 12$).

The Major Right-of-Way was situated on the lower alluvial terrace. Its mean soil temperature at 10 cm depth was 10.5 °C, over 3°C warmer than the adjacent undisturbed soils. As a consequence, soil temperatures along this Bladed Trail were significantly ($p < 0.05$) warmer than both terraces, and slightly higher than the East Talus Control. This disturbance had the warmest soil climate of the three Bladed Trails. It was also the driest, as the average soil moisture at 10 cm depth was 45%, over 100% lower than either the Telephone Line or Minor Rights-of-Way. This was not due to the perturbation, however, as soil moisture was significantly different from that of the lower terrace (53%), nor from the East Talus Control (81%).

In general, soil climates of CANOL disturbances were categorized as:

1) warm and mesic (i.e. Borrow Pits, Bladed Slopes, and Road);

2) moderately warm and mesic (i.e. Major Right-of-Way);

3) hygric and moderately cool (i.e. Telephone Line and Minor Rights-of-Way).

The Controls ranged from mesic on the East, to hygric and cool on the upper terrace of the West Control.

5. INTEGRATION-- FLORISTIC RESPONSES

As was previously discussed in the Introduction, the long-term floristic responses of Subarctic vegetation to disturbance may range from enhancement to degradation. Using the controls as yardsticks, the forty year responses of each CANOL disturbance flora at milepost 40, Dodo Valley, N.W.T. were evaluated.

Five characteristics of the flora were used for the comparisons:

1) plant species composition;

2) plant species richness (R);

3) plant species abundances;

4) plant species equitability (C);

5) relative floristic development.

The multivariate analyses that were conducted (TWINSPAN, DECORANA and CLUSTAN) utilized both species composition and abundance data. Besides plant community classification, these analyses can also provide a measure of floristic development on the disturbances relative to the controls.

5.1 Plant Species Composition

Forty years following CANOL No.1 Project abandonment, there were no plant species occurring exclusively on the disturbances at milepost 40, Dodo Valley, N.W.T. This result, contrasts with Kershaw (1983),who noted that the flora of CANOL disturbances above timberline frequently contained species not present in adjacent controls. Wein and El-Bayoumi (1983) noted that Boreal and Subarctic plant community responses to disturbance are often characterized by changes in species abundances, not composition, however. An analysis of the degree of floristic similarity among the CANOL disturbances and undisturbed controls supported this statement (Table 5.1).

A moderately high degree of floristic similarity existed among all disturbances and undisturbed controls, as Sørensen's Index values ranged from 55 to 80. Index values for the bladed trails and the Road were the highest, as all had scores between 70 and 80. The borrow

Table 5.1: Floristic Similarity Coefficients Comparing Control and CANOL No. 1 Project Disturbance Plant Communities

Milepost 40, Dodo Valley, N.W.T

DISTURBANCE	NO. OF SPECIES	EAST TALUS CONTROL[1]	WEST TERRACE CONTROL[2]	STREAM BED CONTROL[3]
Borrow Pit A	53	60 *	55	48
Borrow Pit B	69	71 *	66	60
Borrow Pit F	56	64 *	55	50
Bladed Slope D	56	60 *	57	56
Bladed Slope G	56	65 *	56	40
Telephone R.O.W.	92	76	80 *	47
Minor R.O.W.	91	78	80 *	45
Major R.O.W.	80	73	75 *	52
Road	86	79 *	72	51

1. Species richness for East Talus Control = 114.
2. Species richness for West Terrace Control = 138.
3. Species richness for Stream Bed Control = 46.

* Indicates control to which this disturbance is most similar.

pits and bladed slopes were 10 to 15 units lower. Sørensen's Stream Bed Control indices were smaller for all CANOL perturbations (Table 5.1).

The relatively high index scores for the bladed trails were expected, since not all of the vegetation was destroyed during construction. As a corollary, the borrow pits and bladed slopes were higher magnitude disturbances. This factor seems to explain their lower Sørensen's values. De Byle (1976), Kershaw (1983), Wein and El-Bayoumi (1983) and Zasada (1986) have also noted similar relationships between disturbance magnitude and species composition. Contradicting the apparent relationships between disturbance magnitude and species composition, were the Road results. This perturbation represented the highest magnitude disturbance, yet had Sørensen's values comparable to the bladed trails (Table 5.1).

"Disturbance area" may account for the Road's relatively high scores. This site was the largest and, therefore, most intensively surveyed disturbance (Section 3.2). As a result, 86 taxa were identified, a value similar to the bladed trails. Since there were no "new" species on the disturbances, Sørensen's Index was largely dependent on species richness. Generally, the higher the R number, the greater the Sørensen's value. For example, the West Terrace Control contained 24 more species than the East Talus Control and, thus, produced a substantially larger denominator during Sørensen's Index calculations (see section 3.5.1). If all of the species on the disturbance were present on both controls, then the East Talus-disturbance Sørensen's index values would be larger. Besides the Road, it was determined that Borrow Pits A and B, and Bladed Slope D were also affected by this phenomenon.

In spite of the inherent bias in Sørensen's Indices, proximity to controls may also have influenced species composition. Borrow Pit F and Bladed Slope G were located in the East Talus community, and both had their highest similarity indices with this control (Table 5.1). An even more convincing result occurred with the bladed trails, all of which were located on the West Terrace controls. These three disturbances had considerably more species in common with the West Terrace control than the East Talus (Table 5.2).

Table 5.2: Number of Species Common to the Bladed Trails and Undisturbed Controls Milepost 40, Dodo Valley, N.W.T.

Disturbance	East Talus	West Terrace
Telephone R.O.W.	78	92
Minor R.O.W.	80	91
Major R.O.W.	71	80

In summary, most sites had moderately high Sørensen's values. Discrepancies among the disturbances appeared to be related to differences in disturbance magnitude, geographic proximity to controls, and species richness. An additional factor may be habitat conditions. For example, fewer pre-disturbance species may have been capable of colonizing the warm and dry bladed slope conditions when compared to the bladed trail soil climates (Kormakova and Webber 1980, Grime and Anderson 1986). Generally, the sites which exhibited the best recovery in terms of species composition were the bladed trails and, with qualifications, the Road. The borrow pits and bladed slopes had fewer species in common with the undisturbed controls and, therefore, were in a more "damaged" state.

The absence of a single taxon occurring exclusively on a disturbance indicates that, after 40 years, species replacement sequences may either be complete or never occurred. The alternative is that rare and, presumably, suppressed individuals in the undisturbed vegetation have proliferated on the disturbances. This process is purportedly operative throughout the North (Viereck 1975, Wein and El-Bayoumi 1983).

5.2 Plant Species Richness (R)

The East Talus and West Terrace controls contained 114 and 138 species, respectively. These values were markedly higher than on the other sites, where R ranged from 48 on the Stream Bed to 92 on the Telephone Right-of-Way (Table 5.3).

Species richness was significantly ($p < 0.05$) correlated with disturbance size and, therefore, sampling intensity. In order to reduce the influence of these two factors on R, the meannumber of species per stand was calculated (Table 5.3). Each stand contained five quadrats.

Differences in R were reduced considerably. Species densities on the two undisturbed controls were identical at 52. Borrow Pits A and B, Bladed Slope G, the Telephone and Major Rights-of-Way all had values comparable to the controls. The Stream Bed and Road had substantially fewer species per stand than the controls, while the Minor Right-of-Way was

Table 5.3: Species Richness-- Controls and Disturbances
Milepost 40, Dodo Valley, N.W.T.

Location	No. of Species	No. of Quadrats	Mean Species Per Stand *	No. of Stands
East Control	114	70	52	7
West Control	138	118	52	12
Stream Bed	48	20	29	2
Borrow Pit A	53	8	50	1
Borrow Pit B	69	9	56	1
Borrow Pit F	56	7	44	1
Bladed Slope D	56	8	46	1
Bladed Slope G	56	5	56	1
Road	86	35	37	7
Telephone R.O.W.	92	25	53	5
Minor R.O.W.	91	20	64	4
Major R.O.W.	80	15	50	3

* Based on 5 quadrats/stand.

considerably higher.

In summary, species density results indicate that the Road, Bladed Slope D and Borrow Pit F were in a damaged state. Each of these CANOL perturbations had values only moderately higher than the Stream Bed. Contrary to this trend, the Minor Right-of-Way appeared to be in an enhanced condition, as it contained 12 more species per stand than either undisturbed control. All other disturbances appeared to have recovered in terms of species density.

The relatively low species density value on the Road and, to a lesser extent, Borrow Pit F and Bladed Slope D, suggests that these sites may have been relatively inhospitable for most pre-disturbance plant species. As previously disscussed, differences in species composition among the disturbances and controls may be related to differences in habitat suitability.

5.3 Growth Form Abundances

Total plant cover on the undisturbed controls ranged from 51% on the East Talus, to 105% on the Upper Terrace of the West Control (Table 5.4). The Stream Bed averaged only 43% cover.

Both terraces were dominated by bryophytes and shrubs, as these two growth forms accounted for over 70% of the total plant cover. In contrast, bryophytes were relatively sparse on the East Talus community, as shrubs and lichens dominated this control (Table 5.4). Only the shrub growth form was common on the Stream Bed. It contributed 85% of the plant cover.

Disturbance communities had total plant covers ranging from 22% on Bladed Slope G, to 108% on the Telephone Right-of-Way (Table 5.4).

Shifts in the relative abundances of each growth form type were evaluated for each disturbance through calculation of growth form cover ratios (Table 5.5). The values were compared with their respective counterparts from adjacent controls.

Table 5.4: Plant Growth Form Covers (%) and 95% Confidence Limits on CANOL No. 1 Disturbances and Controls Milepost 40, Dodo Valley, N.W.T.

	Growth Form Cover (%)							
Site	Tree	Shrub	Forb	Graminoid	Lichen	Moss	Total	n
1. East Talus	7.0±2.7	21.7±2.6	1.6±0.3	3.6±0.7	10.5±3.1	7.0±3.1	50.9±5.9	70
2. West Terrace	6.4±0.9	25±2.0	3.6±2.0	5.1±1.2	15±4.3	45.8±5.1	100±5.8	118
3. West Upper	8.5±1.7	27±3.5	2.4±0.7	4.4±0.7	16.7±4.9	46.8±6.8	105.4±9	58
4. West Lower	4.3±0.9	23.7±2.1	4.8±1.9	5.9±2.2	13.3±4.6	44.9±7.2	96±8	60
5. Stream Bed	1.1±0.6	37±11.8	2.4±1.8	1.7±1.1	0.005±0.01	1.3±1.5	43±15.0	20
6. Borrow Pit A	1.6±1.3	29±15.2	1.7±1.4	7.2±7.1	0	6.2±5.2	25.5±21.4	8
7. Borrow Pit B	4.2±4.9	49±14	4.6±2.9	3.0±1.8	.001±.002	5.3±3.9	66±17	9
8. Borrow Pit F	3.1±2.1	19.6±11.1	0.8±0.6	1.4±1.2	1.7±3.8	6.7±7.7	33.3±16.1	7
9. Bladed Slope D	5.3±3.7	24 ±11.9	2.4±1.4	0.9±1.2	0	1.1±1.4	33.9±12	8
10. Bladed Slope G	1.3±2.6	14.8±5.9	0.9±1.3	4.2±4.8	0.2±0.5	1.1±2.7	22±8.3	5
11. Road	7.1±2.8	57.5±7.1	2.6±2.4	0.5±0.4	0	0.9±0.6	68.5±8	35
12. Telephone ROW	5.2±1.9	33.4±6.6	2.6±0.9	7.8±4.9	10.6±6.8	48.8±12.4	108±12.1	25
13. Minor ROW	2.3±1	30.3±4	5.6±4.2	7.7±2.2	8.2±6.8	31.6±13.4	85.1±18.8	20
14. Major ROW	0.3±0.1	29.1±7.8	4.0±1.6	16.6±11.6	6.6±7.1	23.6±13.3	79.3±12	15

Perhaps because of reduced competition for resources, particularly light, from a sparser tree layer the two upper terrace bladed trails (Telephone and Minor Rights-of-Way) exhibited an increase in the relative importance of all understory growth forms. Shrubs and bryophytes had the greatest change. Only shrubs and graminoids increased their importance on the Lower Terrace's Major Right-of-Way. All other growth forms were either identical (forb), or lower (tree and non-vascular plants), than the Lower Terrace values (Table 5.4).

The borrow pits and bladed slopes were compared to the East Talus Control. Shrub species such as *Dryas drummondii, D. integrifolia, Salix* spp., often rapidly establish and dominate bare surfaces (Grime and Anderson 1986, Zasada 1986). Their dominance is often usually only reduced following establishment of a coniferous tree canopy (Grime and Anderson 1986). Borrow pits were characterized by a decrease in tree and lichen importance, coupled with an increase in the shrub value. Graminoids were also more important in Borrow Pit A. Tree, shrub and forb growth forms had greater ratios in Bladed Slope D, while the graminoid, lichen and bryophyte values declined. Only graminoids were more abundant on Bladed Slope G than on the East Talus Control. The importance of shrubs was substantially greater on the Road than either the East Talus or Upper Terrace Control. With the exception of forbs, all other growth forms had lower values (Table 5.4).

Considering that plant community recovery had been natural, it was interesting that a substantial portion of the plant cover had been restored on most sites. Even high magnitude perturbations, such as the Road and Borrow Pit B, had cover values which exceeded the East Talus Control. Kershaw (1983) also recorded relatively high plant cover restoration in alpine communities, even on severe disturbances such as CANOL borrow pits. Almost all sites at mile post 40, Dodo Valley, exhibited a shift in growth form abundances. Understory vascular plants achieved higher covers on the bladed trails when compared to adjacent controls. Shrub was the major growth form on the higher magnitude disturbances. Over all, Borrow Pits A and F, and the two bladed slopes still appeared to be negatively affected by the disturbances as they had considerably lower cover values than nearby controls.

Table 5.5: Proportionate Abundances of Growth Forms on CANOL Disturbance and Control Plant Communities
Milepost 40, Dodo Valley, N.W.T.

Site	Growth Form Tree	Shrub	Forb	Graminoid	Lichen	Bryophyte
East Talus	4.4	13.6	1.0	2.3	6.6	4.4
West Terrace:	1.8	6.9	1.0	1.4	4.2	12.7
West Upper	3.5	6.1	1.0	1.8	3.8	10.6
West Lower	1.0	5.5	1.1	1.4	3.1	10.4
Stream Bed	1.0	33.6	2.2	1.6	<1.0	1.2
Borrow Pit A	1.0	18.1	1.1	4.5	0	3.9
Borrow Pit B	1.4	16.3	1.5	1.0	<1.0	1.8
Borrow Pit F	2.2	14.0	<1.0	1.0	1.2	4.8
Bladed Slope D	4.8	21.8	2.2	<1.0	0	1.0
Bladed Slope G	1.2	13.5	<1.0	3.8	<1.0	1.0
Road	2.7	22.1	1.0	<1.0	0	<1.0
Telephone R.O.W.	2.0	12.9	1.0	3.0	4.1	18.8
Minor R.O.W.	1.0	13.2	2.4	3.4	3.6	13.7
Major R.O.W.	<1.0	7.3	1.0	4.2	1.7	5.9

Shifts in growth form abundances appear to be the most apparent floristic response on the CANOL perturbations at mile 40. Whether these shifts resulted in more or less even distributions of abundance amongst each site's component species was calculated using Simpson's Index of Dominance Concentration (C).

5.4 Species Equitability

Borrow Pits A and F, the Minor and Major Rights-of-Way each had a more even distribution of abundances amongst the species (i.e. were more equitable) than either control. No single taxa or small group of species was clearly dominant on these sites (Table 5.6) Of the remaining CANOL disturbances, only the Road had a substantially lower species equitability. In fact, the C value of this perturbation was comparable with the Stream Bed's. In both cases, total plant cover was primarily accounted for by a single species, *Dryas drummondii* (see Tables 4.3 and 4.9).

Simpson's Indices revealed two other noteworthy results:

1) All bladed trail plant communities were more equitable than the adjacent West Terrace control community;

2) The bladed slopes had markedly lower species equitability than the more intensively disturbed borrow pits.

In fact, the mean Simpson's Index for the three borrow pits (0.102) was lower than that of the bladed trails' (0.107). This result was surprising, considering that the latter disturbances were considered to have more amenable growth conditions, and were lower magnitude perturbations. Rafting may have contributed to the increase in species equitability in the borrow pits.

It appears as though neither disturbance regime or habitat variables were related to long-term equitability characteristics. In general, the borrow pit and bladed trail vegetation was more equitable than the undisturbed control vegetation. These sites were thus considered enhanced. Both bladed slopes were less equitable than the Controls and, therefore, were

Table 5.6: Simpson's Index of Dominance Concentration
Controls and Disturbances
Milepost 40, Dodo Valley, N.W.T.

Site	Simpson's Index (C)	Number of Stands
Borrow Pit A	0.088	1
Minor R.O.W.	0.096	4
Borrow Pit F	0.102	1
Major R.O.W.	0.104	3
East Talus Control	0.105	7
Borrow Pit B	0.117	1
Telephone Line R.O.W.	0.122	5
West Terrace Control	0.140	12
Bladed Slope G	0.164	1
Bladed Slope D	0.165	1
Road	0.433	7
Stream Bed Control	0.540	2

considered moderately damaged. The CANOL Road, with a C value over three times higher than either undisturbed control, was most similar to the Stream Bed. This site still must undergo considerable recovery before pre-disturbance equitability is restored.

The preceding analyses revealed that substantial differences in species abundances existed among the sites. Although there were no non-predisturbance taxa on the perturbations, there were some species compositional differences as well.

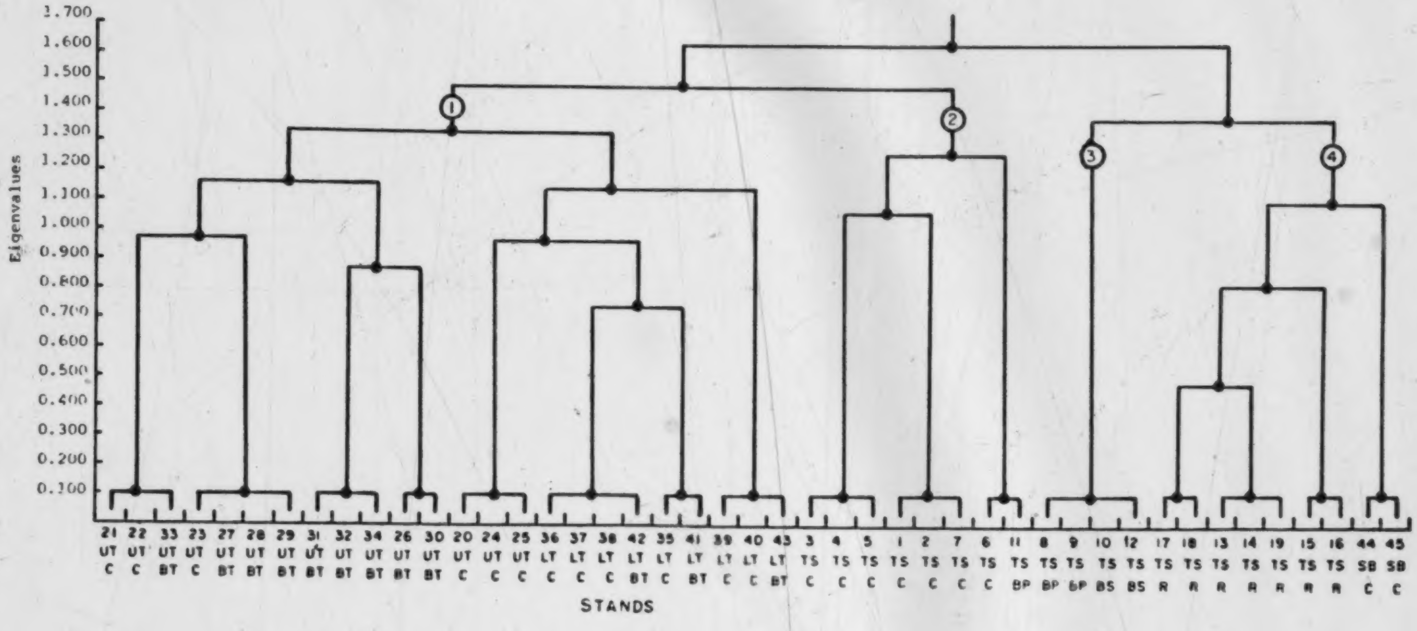
Multivariate analyses uses both species composition and abundance data for site comparisons. These analyses, therefore, integrate the above-listed responses and provide succinct expressions of relative floristic development.

5.5 Relative Floristic Development

Multivariate analyses (TWINSPAN and DECORANA) were used to evaluate the degree of floristic recovery following CANOL disturbances at Milepost 40, Dodo Valley, N.W.T. (Figures 5.1 and 5.2). The DECORANA axis scores were particularly helpful for this purpose, since they expressed similarities among the flora in terms of distance. These distance values, therefore, signified relative floristic development, when compared to the control communities.

Incorporation of all bladed trail and one borrow pit stand into the previously identified East Talus and West Control clusters (see Figure 4.1), signified their recovery in terms of species composition and abundance. The Telephone, Minor and Major Rights-of-Way were included in the West Terrace Control cluster, while Borrow Pit F was included in the East Talus cluster (Figures 5.1 and 5.2). The remaining two borrow pits, as well as the three bladed slopes formed an additional cluster, while the Road and the Stream

Figure 5.1: Classification of Control and Disturbance Vegetation at milepost 40, Dodo Valley N.W.T.



Key

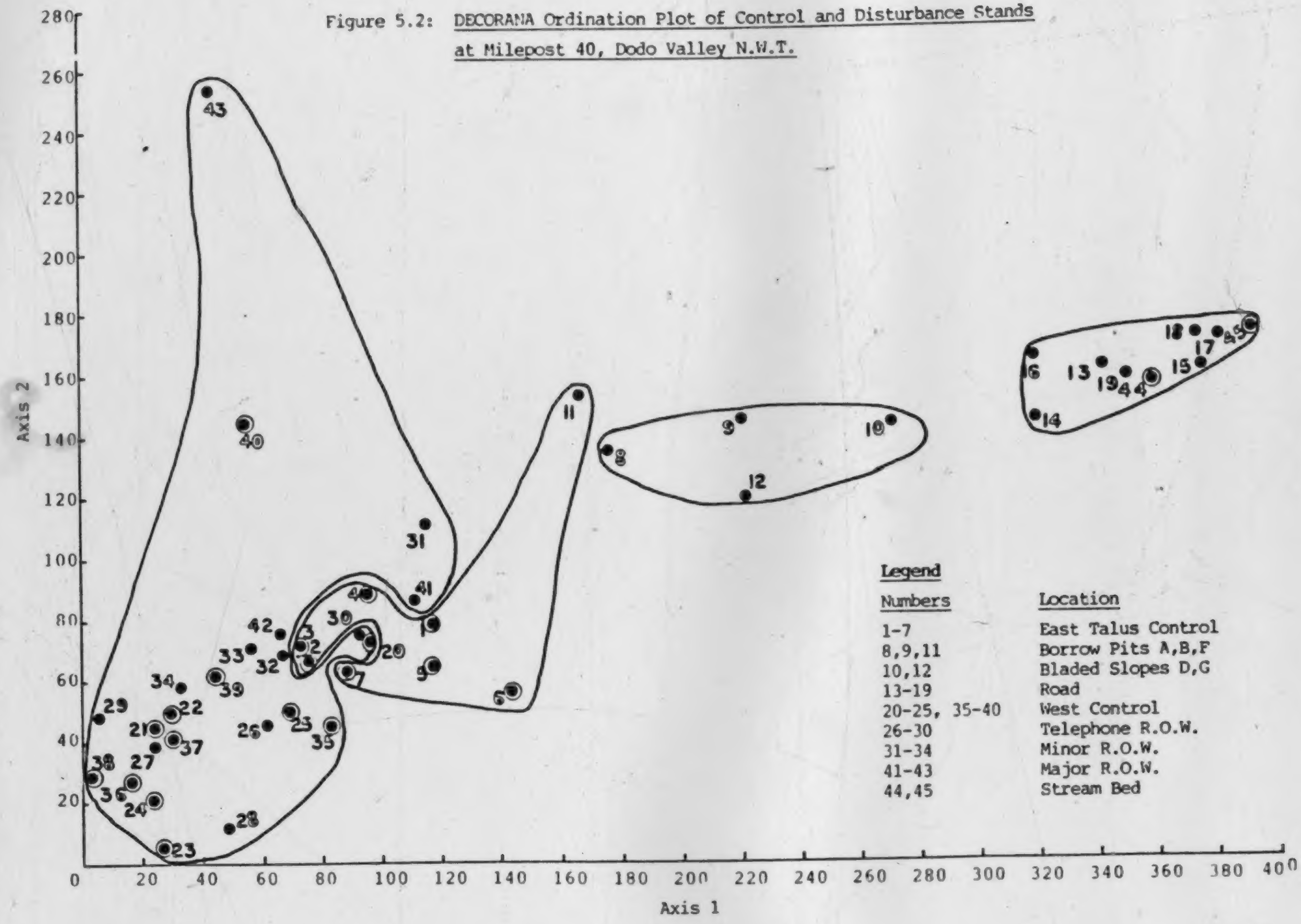
Landform

UT = Upper Terrace
LT = Lower Terrace
TS = Talus Slope
SB = Stream Bed

Disturbance Type

C = Control
BT = Bladed Trail
BP = Borrow Pit
BS = Bladed Slope
R = Road

Figure 5.2: DECORANA Ordination Plot of Control and Disturbance Stands at Milepost 40, Dodo Valley N.W.T.



Bed stands composed another. As no undisturbed stands were present these sites were considered to be:

a) in a damaged state;

b) enhanced or;

c) neither of the above, but merely contained enough "new characteristics" (e.g. species) to be excluded from the undisturbed controls.

Generally, the West Terrace control and bladed trails represented the best developed sites. All had relatively high plant covers, were species rich, and had even distributions of abundance among their component species (low C values). Other vegetation stands were less developed and thus approached the stream bed in the ordination diagram (Figure 5.2).

When viewed in this manner, the Road was the most damaged. In fact, this perturbation formed a cluster with the Stream Bed (Figures 5.1 and 5.2). The bladed slopes were also relatively poorly developed, followed by the borrow pits.

A more detailed examination of the clusters revealed the presence of distinct sub-clusters. The West Terrace Control-- Disturbance cluster (No. 1) and cluster number three each contained two such entities.

The first sub-cluster of number one was composed of control stands DC, DD, and DE, plus all Telephone (EC to EG) and Minor Rights-of-Way (FC to FF) Stands. The second sub-cluster contained nine control and all three Major Right-of-Way stands. The two sub-clusters from cluster number three were composed of: 1) Borrow pit and bladed slope disturbances, and 2) the Road and Stream Bed control.

Several conclusions were drawn from this clustering pattern:

1) The disturbance flora most closely resembled that of similar disturbance types and/or nearby controls;

2)The borrow pit and bladed slope flora was intermediate between the East Talus control and the Road. This suggested that the East Talus control, borrow pits and bladed slopes represented a floristic continuum between the stream bed and undisturbed communities.

As discussed in Section 3.5.1, multivariate analyses uses both species composition and abundance attributes. CLUSTAN analyses (Ward's method) was employed to help assess the importance of each attribute type in cluster formation. This analysis revealed that the major difference among the 45 stands was species abundance. The dissimilarity coefficient derived from "raw" data (where cover values were emphasized), was 188.5. Emphasis on differences in species composition produced a value of only 7.2. This result supported the Sørensen's index results, which found there were few compositional disparities among the sites.

5.6 Discussion

After 40 years, CANOL disturbance vegetation encompassed a wide spectrum of development, ranging from sites which had recovered in most respects (e.g. bladed trails), to those which supported distinctly different plant communities (e.g. the Road). The major disparity between the disturbance plant communities and their controls was a shift in plant species abundances. Generally, understory vascular growth form cover was either restored or they exceeded control values. In contrast, tree and non-vascular plant covers declined, particularily on the higher magnitude disturbances. These were represented by the Road, Borrow Pits and Bladed Slopes. Although there were no non-predisturbance taxa on the perturbations, species compositional differences did exist among the sites.

Observations of relatively short-term (< 30 years) natural revegetation following perturbations in other non- or deep- permafrost areas of the Subarctic have also indicated a broad variability of plant community responses. Differences in recovery have been largely attributed disturbance magnitude.

As was the case for the three bladed trails at mile 40, plant community recovery following incomplete vegetation and soil destruction has not resulted in markedly different floras elsewhere (Hernandez 1973, Dabbs et al. 1974, Anonymous 1976, Johnson and Rowe 1977, Dyrness et al. 1986). This is primarily because much of the revegetation following clearcutting or fires of moderate or lighter severity has occurred from the resprouting of undamaged rootstocks (Bell et al. 1974, Reid and Janz 1974, Viereck et al. 1979). In addition, invasion by seed propagules is considered minimal, although it varies depending on the amount of organic matter removed from the surface and the species composition of the predisturbance vegetation (Reid and Janz 1974). Since all plant species on the three bladed trails at mile 40 were also present in the adjacent undisturbed vegetation the invasion and persistence of long-distance dispersers was probably minimal or non-existent.

The principal resprouters and vegetative reproducers are usually grasses, sedges and shrubs (Hernandez 1974a, Wein 1975). In situations where the understory vegetation has been relatively undisturbed, a dense shrub or grass cover has commonly developed within two to three years. Reid (1974) observed that shrubs resprouted and reestablished their cover or exceeded pre-disturbance levels on four-year-old seismic lines and winter roads in the Mackenzie Valley, NWT. All three bladed trails were dominated primarily by shrubs, although sedges were also abundant on the Major Right-of-Way. If Reid's (1974) time-frame were appropriate for CANOL perturbations then the dense understory may have persisted for as long as 35 to 38 years.

Common resprouters noted elsewhere throughout the Subarctic were also important on the CANOL bladed trails. They included *Alnus crispa, Salix* spp., *Ledum groenlandicum, Arctostaphylos rubra, Betula glandulosa, Vaccinium uliginosum,* and *Rhododendron lapponicum* (Hettinger 1973, Hernandez 1974b, Reid and Janz 1974, Riewe 1977, Zasada 1986). *Carex* spp. and two grasses *Calamagrostis canadensis* and *Arctagrostis latifolia* are the graminoid species which often tend to produce extensive swards on cutlines (Bell et al. 1974, Dabbs et al. 1974, Wein 1975, Younkin 1973, Riewe 1977). These taxa were rare on the upper terrace bladed trails and as such, probably had not prolifertated on these disturbances. Wein (1975) noted that these species may persist for ten years. Although this would have allowed sufficient time for these graminoids to dominate and then decline, it probably did not occur owing to the abundant shrub cover. *Carex membranacea*, however, was locally abundant on the Major Right-of-Way. This taxon appears to have been well-adapted to conditions of periodic soil saturation, particularily in depressions where it was most abundant.

The relatively rapid growth and dominance of understory plant species on the milepost 40 bladed trails may have accounted for the restricted tree regeneration. Tree seedling germination was likely prevented because of a reduction in light intensity and/or drier soil regimes at the surface (Bell et al. 1974, Wein and El-Bayoumi 1983). As a corollary, others have observed the relatively rapid establishment of conifer and deciduous seedlings where the understory had not produced an extensive vegetative cover (Reid and Janz 1974, Riewe 1977).

Abiotic factors can also prevent short-term tree regeneration (Mikola 1970, Gill 1973b, Hernandez 1974a, Wein 1975). Gill (1973b) and Mikola (1970) both noted that clearcutting may result in a sufficient degradation in microclimate to inhibit tree seedling germination. Riewe (1977) observed that eroded seismic lines tend to support few *Picea* spp. seedlings when compared to surfaces with intact organic horizons.

The higher magnitude Road, Borrow Pit and Bladed Slope disturbances were colonized the least rapidly and successfully. Two prostrate evergreen species *Dryas drummondii* and *D. integrifolia* dominated the plant cover on these sites. Hardwood trees, broad-leaf deciduous shrub and herb species were also common, while non-vascular plant species were sparse. The sparseness of bryophytes and lichens was not surprising since non-vascular plant species, particularily lichens, are generally slow colonizers (Hettinger 1973, Johnson and Rowe 1977, Riewe 1977). Other research indicates that development of this type of flora occurs relatively quickly (Reid and Janz 1974, Hernandez 1973, Johnson and Kubannis 1980). Well-drained soils on the Yukon River - Prudhoe Bay Alaska Haul Road exemplify what initially happens on most newly created gravel surfaces. A relatively large number (31) of opportunistic species, but few (10) persistent ones, colonized the road in 1977 (Johnson and Kubannis 1980). Two years later eleven opportunistic taxa remained, but all ten persistent species were still there. Taxa which dominated this and other similar sites throughout the Subarctic included *Equisetum* spp., *Epilobium* spp., *Alnus* spp., *Salix* spp., *Populus* spp., *Potentilla fruticosa, Dryas drummondii,* and *Shepherdia canadensis* (Hettinger 1973, Hernandez 1974b, Reid 1974). These plant species also colonized and perhaps more importantly, persisted on the Road, Borrow Pit and Bladed Slope disturbances in the Dodo Valley. Their importance will probably decline, however, since *Picea glauca* seedlings and saplings were abundant in the understory of all sites. Non-vascular plants should also increase with time because of increased nutrient supply from *Picea glauca* canopy drip, and reduced evapotranspiration (Hettinger 1973, Johnson and Rowe 1977).

6. RELATIONSHIPS AMONG HABITAT, DISTURBANCE AND PLANT COMMUNITY CHARACTERISTICS

6.1 Disturbance and Habitat Relationships

6.1.1 Disturbance Component

The characteristics of each CANOL disturbance at Milepost 40, Dodo Valley, N.W.T. were quantified in terms of intensity, severity, terrain sensitivity, area and perimeter:area. Intensity is often cited as the most important disturbance component influencing site recovery (Gill 1973a, Kormakova and Webber 1980, Zasada 1986). For example, Kormakova and Webber (1980) and Wein and El-Bayoumi (1983), among others, have asserted that the ecosystem recovery period increases with perturbation intensity. Kershaw (1983) noted, however, that in Alpine areas, certain floristic attributes had recovered from CANOL perturbations, seemingly independent of intensity. Gravel pit access roads periodically achieved plant covers comparable to bulldozer track sites and adjacent controls, only 35 years later.

The lack of a clear relationship between intensity and recovery may be due to the modifying effect of the other disturbance components. Heginbottom (1973) implied a positive, linear relationship between intensity and severity, and, therefore, plant community recovery. Area, perimeter:area, and terrain sensitivity can distort this correlation. For example, floodplains within the immediate vicinity of rivers and streams are less sensitive to disturbance, than more poorly drained and, often, ice-rich terraces located above the floodplain (Kurfurst 1973). Vegetation destruction and habitat modification on these latter site types will be more extensive than on the floodplain due to thermokarst (Kurfurst 1973).

Disturbance shape can also influence plant community recovery (Bell et al. 1974, Zasada 1986). Bell et al. (1974) predicted that the similarity in species composition among perturbed and control plant communities will decline as perimeter:area increases. Contradicting this prediction were the observations of Bliss (1973) and Wein and El-Bayoumi

Table 6.1: Kendall's Rank-Order Correlations Between Disturbance Regime Variables (n=12)

Milepost 40, Dodo Valley, N.W.T.

	Area	Perimeter to area	Terrain Sensitivity	Intensity	Severity	
					Shrub Destr'n	Micro.^{2} Change
Area	1.0	-.35	-.81	-.63	-.71	-.14
Perimeter to Area	-.35	1.0	.25	.33	.32	.61
Terrain Sensitivity	-.80^A	.25	1.0	.76	.92	-.29
Intensity	-.63^A	.33	.76^A	1.0	.87	.34
Shrub Destruction	-.71^A	.32	.92^A	.87^A	1.0	.40
Micro.^{2} Change	-.14	.61^A	.29	.34	.40	1.0

1. Association values (Tau) followed by the letter "A" indicates significant ($p < 0.01$) correlation.

2. Abbreviation for "Microtopographical."

(1983), and the results of this study. The primary response of the plant communities at milepost 40 to disturbance was not a shift in species composition, but in species abundance. Perimeter:area would not be relevant in these situations.

Relationships among the disturbance variables at milepost 40 were assessed with the aid of statistical analyses. Intensity, one severity descriptor (shrub destruction), and terrain sensitivity were all significantly ($p<0.05$) associated with one another. Generally, the smallest disturbances were also the most intense and severe. They also tended to be located on the most sensitive terrain. The other descriptors, perimeter:area and microtopographical change, generated small (<0.5), and non-significant correlation coefficients. These descriptors were ,therefore, assumed to be either independent of the other disturbance characteristics, or too variable. As a consequence the disturbances could be described adequately with one of these descriptors. Intensity was selected. It was given priority over severity because the model upon which its values were based were not a product of this study. Terrain sensitivity and area were "passive" variables, as their effects were not realized until after the CANOL perturbations had been initiated.

CANOL sites were placed into three intensity classes:

1) undisturbed control (intensity = 0);
2) moderate (intensity = 6);
3) extreme (intensity = 8 to 10).

Class one sites were the East Talus and West Terrace Control. Moderate disturbances encompassed all three bladed trails, while the borrow pits (9), bladed slopes (8), and road (10) comprised the Extreme class.

6.1.2 Habitat Component

Vegetation dynamics in the Subarctic, such as seedling establishment, productivity, plant maturation, and species replacement are governed by numerous interrelated abiotic factors. Soil moisture and soil temperature regimes, and soil nutrient status are considered to be particularly important in this regard (Viereck et al. 1983, Heal and Vitousek 1986, Van

Table 6.2: Spearman's Rank-order Correlations Among Soil Physical and Chemical Characteristics and Non-Vascular Plant Cover (n=43), Milepost 40, Dodo Valley, N.W.T.

	Soil Moisture	Soil Temperature	pH	Organic Matter	Non-vascular Cover
Soil Moisture	1.00	-0.79	-0.72	0.81	0.78
Soil Temperature	-0.79^{a}	1.00	0.63	-0.69	-0.81
pH	-0.72	0.63^{a}	1.00	-0.79	-0.64
Organic Matter	0.81^{a}	-0.69^{a}	-0.79^{a}	1.00	0.67
Non-vascular Cover	0.78^{a}	-0.81^{a}	-0.64^{a}	0.67^{a}	1.00

1. Association values (Rho) followed by the letter "a" indicate significant ($p < 0.01$) associations.

Cleve and Yarie 1986).

Soil micro-climate is directly related to surface temperature and ground-heat flux (Haag 1974, Sellers 1974, Van Cleve and Yarie 1986). These two conditions are primarily governed by two habitat modifiers: organic matter content and non-vascular cover (Van Cleve et al. 1983, Viereck et al. 1983, Van Cleve and Yarie 1986).

For example, soil micro-climate affects decomposition rates and, thus, the nutrient status of a soil. A site characterized by an extensive moss carpet, and relatively deep and organic matter-rich surface horizon, will have a comparatively cool and moist soil climate. This site will also tend to be nutrient-poor. In contrast, a soil surface typified by little or no organic matter, nor by an extensive non-vascular layer, may also be oligotrophic, but usually has a warmer and drier soil climate (Pettapiece and Zoltai 1974, Sellers 1974, Van Cleve et al. 1983). At Milepost 40, Dodo Valley, N.W.T., the abandoned stream bed exemplified the former condition, while the upper alluvial terrace typified the latter.

Spearman's Rank-Order Correlations, Rho, were performed to test for correlations among two habitat modifiers (non-vascular plant cover and percent organic matter), with soil moisture, soil temperature, and surface pH from the disturbances and controls (Table 6.2). All three habitat conditions were strongly correlated with the two modifiers. Generally, soil moisture tended to increase with organic matter and non-vascular plant cover, while surface pH and soil temperature decreased.

6.1.3 Relationships Between Habitat and Disturbance Intensity

Undisturbed vegetation at Milepost 40, Dodo Valley, N.W.T. contained coniferous tree species in excess of 400 years old, an extensive carpet of feathermosses and lichens, and an organic matter-rich forest floor soil. These attributes are typical of nutrient accumulation sites (Van Cleve and Yarie 1986). These site types accumulate the largest portion of their biomass and nutrients in the relatively cool and wet forest floor. Severe disturbances such as flooding, fire and seismic line construction, can produce marked changes in the habitat conditions of these sites (Haag 1974, Pettapiece and Zoltai 1974). Removal and/or compaction of the organic matter and non-vascular plants, alters the thermal properties (lower albedo, higher conductivity, lower heat capacity) of the forest floor (Seliers 1974, Van Cleve and Yarie 1986). Soils may be warmer, due to greater ground-heat flux, and drier, particularly if mineral soil is exposed (Pettapiece and Zoltai 1974).

Habitat quality is most strongly associated with the disturbance characteristics during the period immediately following an event such as fire or clearcutting. This relationship dissipates over time as internal control of the abiotic environment by the vegetation increases (Tranquillini 1979, Grime and Anderson 1986). Restoration of the pre-disturbance vegetation may require hundreds of years, however (Pettapiece and Zoltai 1974, Wein and El-Bayoumi 1983). If this time frame is appropriate for the CANOL disturbance communities at Milepost 40, significant differences in habitat quality should exist. To test for this, Mann-Whitney U Two Sample comparisons (Sokal and Rohlf 1981) were conducted on the soil moisture, soil temperature and pH characteristics of undisturbed controls, and disturbances of moderate and extreme intensity (Table 6.3).

Undisturbed controls had slightly cooler and drier soils than the bladed trails, while pH was virtually identical. None of these differences were statistically significant, however. Minimal long-term disruption of the soil surface on the bladed trails accounted for the growth condition similarities. This was evidenced by the fact that organic matter content was also not statistically different among bladed trails and undisturbed controls (Table 6.3).

In contrast, all three habitat conditions on the road, borrow pits, and bladed slopes were significantly ($p<0.05$) different from the undisturbed controls and bladed trails (Table 6.3). Compared to the controls, soil temperature was over five ^{o}C warmer, mean soil moisture almost 85% lower, and pH over one unit higher. The production of a statistically significant differences in habitat quality on these sites appeared to be a consequence of disturbance intensity. Organic matter content, which had, presumably, been completely removed during CANOL Road, borrow pit and bladed slope construction, was still virtually non-existent 40 years later.

Table 6.3: Mann-Whitney U Two Sample Comparisons of Soil pH, Soil Climate, and % Organic Matter Among Undisturbed Controls and Disturbances of Moderate and Extreme Intensity (n=12), Milepost 40, Dodo Valley, N.W.T.

	Habitat Indicators			Ground Surface Characteristic
Disturbance Intensity	Soil Temperature (°C at 10cm)	Soil Moisture (% Oven-dry Wt. 10cm)	pH (DD H_2O)	Organic Matter (% Oven-dry Wt. Surface Horizon)
6[2]	8.3 ± 1.8A	144.7±73.4B	6.9 ± 0.4E	36.1 ± 16.9C
8 - 10[3]	12.5 ± 0.9	10.6± 1.2	7.8 ± 0.1	2.6 ± 0.8
Conntrol[4]	7.0 + 1.2A	94.4±33.2B	6.7 ± 0.4	35.3 ± 10.8C

1. Adapted from Heginbottom 1973; see Section 3.4.3, Appendix 2.
2. Telephone Line, Minor and Major Rights-of-Way.
3. Bladed Slopes (intensity= 8), Borrow Pits (9), Road (10).
4. East Talus Control; West Terrace Control.
5. Mean ± 95% confidence limits. Common letters indicate means that are significantly ($p < 0.05$) different.

Soil temperature and pH differences between perturbations of moderate and extreme intensity were less marked, but still significant. Soil moisture disparities were even more pronounced. This may be due to a slightly higher organic matter content on the bladed trails, compared with the controls (Table 6.3).

In summary, CANOL No. 1 Project disturbances at Milepost 40, Dodo Valley, N.W.T. seemed to have had long-term effects on habitat quality. Generally, the habitat of sites inundated by perturbations of moderate intensity did not differ significantly from undisturbed controls. They did tend to have warmer and moister soil climates. The growth conditions for plants on sites of more intense perturbations (road, borrow pits, and bladed slopes) were significantly warmer and drier, and had higher pH values.

6.2 Disturbance, Habitat and Vegetation Relationships

Disturbances act as catalysts for vegetation change, directly through varying degrees of plant destruction, and indirectly by modifying growth conditions. The strong statistical relationships between characteristics of the CANOL Project disturbances with habitat seemed to confirm the existence of these potential indirect effects. Considering the lengthy recovery period for Subarctic plant communities following high magnitude perturbations, the floristic responses at Milepost 40 may be directly correlated with disturbance characteristics as well.

The major floristic disparity among control and disturbance plant communities, was growth form abundance. Statistical tests comparing growth form covers with habitat and disturbance attributes were conducted. Ordination scores were also tested against these two sets of variables, since their values also incorporated species composition characteristics.

6.2.1 Comparisons of Disturbances and Growth Form Abundances

Tests of association between growth form cover classes and six disturbance regime descriptors were performed using Kendall's Rank-Order Correlation, (Tau)(Table 6.4).

Generally, most plant cover categories were not significantly correlated with the disturbance regime variables. Only 26% of the 42 tests were significant ($p<0.05$), and just 7%

Table 6.4: Kendall's Rank-Order Correlations Between Growth Form Covers (%) and Disturbance Regime Variables (n=12)

Milepost 40, Dodo Valley, N.W.T.

Growth Form	Disturbance Regime Variables[1] Spatial Extent (m^2)	Perimeter: Area	Terrain Sensitivity	Intensity	% Shrub Destruction	Microtopographical Change
Total	0.52a	-0.15	-0.63a	-0.36	-0.53a	-0.08
Tree	0.48a	-0.41	-0.31	-0.13	-0.21	-0.20
Shrub	0.03	0.23	0.07	0.29	0.18	0.36
Forb	0.12	0.14	-0.27	-0.14	-0.20	0.24
Graminoid	-0.06	0.14	-0.24	-0.36	-0.39	-0.08
Moss	0.42	-0.18	-0.52a	-0.56a	-0.60a	-0.36
Lichen	0.64a	-0.24	-0.75a	-0.78a	-0.78a	-0.37

1. Refer to Section 4.2.1 for discussion of disturbance regime variables.

2. Down the columns, association values (Tau) followed by the letter "a" indicate significant ($p < 0.05$) association.

had Taus greater than 0.7. This suggests that either:

1) the disturbance factors never were associated with species abundances. This would includes perimeter:area and microtopographical change;

2) or dominant disturbance variables masked the effects of subordinate ones. For example, terrain sensitivity had a moderately strong association with total plant cover (-0.63). The influence of intensity may have been obscured, as its Tau value was substantially smaller at -0.36. Although this conclusion is difficult to substantiate, the effects of disturbance area and perhaps microtopographical change may also have been obscured because of this factor;

3) correlations have become weaker with time, as the disturbances recovered. The strongest correlations were with lichen and moss cover, which not surprisingly, are the slowest plants to colonize disturbances. The long-term effects of disturbance shape, magnitude and terrain sensivity on vascular plant species abundance was minimal. The cover of most growth forms on the disturbances were statistically the same as their counterparts on the undisturbed controls.

Perimeter:area and microtopographical change had no significant association ($p >> 0.05$) with any other cover class. An absence of a significant correlation among perimeter:area and cover values was not surprising, as this disturbance variable was considered by Bell et al. (1974) to influence composition but not abundance. The remaining four disturbance variables had a statistically significant association ($p < 0.05$) with at least one plant cover category.

Based on a sample of just 12, disturbance intensity had a significantly negative association with moss and lichen cover (Table 6.4), while disturbance severity, as estimated by percent shrub destruction, had significantly negative correlations with total plant, moss and lichen abundance. This indicated that, as disturbance magnitude increased, non-vascular plant covers tended to be lower, even after 40 years. The strengths of the correlations among these two disturbance variables with growth form cover categories were approximately equal. One difference was that severity was significantly associated with total plant cover, whereas intensity was not (Table 6.4).

Generally, there were relatively few strong (tau or rho >> 0.65) correlations among the disturbance and growth form abundance variables. Lichen and bryophyte categories were the most significantly affected species, as their covers were negatively associated with disturbance magnitude and terrain sensitivity. These disturbance variables were strongly correlated with one another. As a consequence, only disturbance intensity was selected for subsequent statistical tests with species abundances.

6.2.2 Relationships Among Habitat Conditions and Growth Form Abundances

Associations between habitat variables and growth form abundances on the disturbances and controls were evaluated statistically through calculations of Spearman's Rank-Order Correlation Coefficients (Rho). Correlations were produced among seven growth form cover categories and soil temperature, soil moisture, and surface pH (Table 6.5).

A total of ten significant ($p<0.05$) correlations, out of 22 possible, were generated. Of these, five were at least moderately strong (Rho >>0.65). When compared to the disturbance regime variables, there were over 20% greater significant relationships, and a 14% increase in the number of moderately strong correlation coefficients (Tables 6.4 and 6.5). This result suggested that habitat may have been more closely tied to growth form abundance than were disturbance characteristics. A more plausible explanation for the increased number of statistically significant correlations among the habitat variables and cover values, when compared to the disturbance descriptors, was sample size (n). For example, n for each habitat variable was 43, whereas, the sample size for each disturbance descriptor was only 12. Statistical differences between disturbance and habitat effects on growth form abundance, therefore, was probably a function of sample size. Whether habitat or disturbance was more important for site recovery over the 40 year period was not really discernible.

Vascular plant cover did not produce any statistically significant correlations with the habitat variables. In contrast, the abundance of the non-vascular plants, particularly the lichens, did.

Table 6.5: Spearman's Rank-Order Correlations (Rho) Between Growth Form Covers (%) and Soil Physical and Chemical Properties (n=43) Milepost 40, Dodo Valley, N.W.T.

Growth Form	Soil Temperature (°C at -10cm)	Soil Moisture (% at -10cm)	pH (DD H_2O)
Total	-0.64[a1]	0.59[a]	-0.41[a]
Tree	-0.15	-0.0042	-0.02
Shrub	0.28	-0.23	0.28
Forb	-0.08	0.20	0.09
Graminoid	-0.31	0.45[a]	-0.23
Moss	-0.73[a]	0.71[a]	-0.57[a]
Lichen	-0.79[a]	0.74[a]	-0.69[a]

1. Association values (Rho) followed by the letter "a" indicate significant ($p < 0.01$) association.

'Graminoid' was the only vascular plant category which produced significant ($p<0.05$) associations with the habitat variables, however, the Rho values were weak. In terms of growth form, vascular plants were well-adapted to the full spectrum of plant conditions present at Milepost 40, Dodo Valley, N.W.T., although the dominant species were different (see chapter 4). Abundant vascular taxa on the exposed road and bladed slope disturbances included *Dryas drummondii, Dryas integrifolia,* and *Populus balsamifera.* Although possessing similar habitat conditions, the more protected, concave-shaped borrow pits were dominated by *Dryas integrifolia, Salix alaxensis, Betula glandulosa,* and, in Borrow Pit B, *Alnus crispa.* The more mesic bladed trails also had an abundance of *Betula glandulosa* and *Dryas integrifolia.* Other common species included *Ledum groenlandicum, Salix myrtillifolia, Vaccinium uliginosum, Arctostaphylos rubra,* and *Potentilla fruticosa.* With the exception of *Dryas drummondii* and *Salix alaxensis,* all of these taxa were common in the undisturbed controls as well.

Soil temperature and, to a lesser extent, soil moisture and surface pH, generated relatively strong correlation coefficients with the covers of non-vascular plant species. Bryophyte and lichen abundance were negatively correlated with temperature and pH, and positively with moisture (Table 6.5). Lichen cover produced the largest Rho values for all three habitat variables, while the bryophytes' slightly smaller. These results were similar to those produced among disturbance regime variables and species abundances, where lichens and bryophytes generated the largest Tau values.

As previously discussed, forest floor habitat conditions are governed, in part, by non-vascular plants. Lower soil temperatures and pH, and higher soil moisture values on bryophyte- and lichen-dominated sites illustrates the importance of non-vascular plant species in regulating soil climate. As a corrollary, soil conditions following severe fire, flooding, or road construction, and therefore, unmodified by plants are comparitively warm and dry (Van Cleve and Dyrness 1983, Grime and Anderson 1986). Nutrient turnover rates are consequently also relatively high (Heal and Vitousek 1986). Shrubs, herbs, and deciduous trees are well-adapted to these conditions, and usually dominate (Dyrness et al. 1986). *Picea* spp. also frequently establish during this period but, due to inherent slow growth rates, are confined to the understory.

As the correlation coefficients have indicated, the habitats on the road and bladed slopes, and in the borrow pits, seem to have been unfavourable for the establishment of non-vascular plants over the past 40 years. The shading effects produced by the understory plants combined with the smothering resulting from the high litter fall, also may have inhibited non-vascular species' establishment (Heal and Vitousek 1986). One exception was *Drepanocladus uncinatus*, as this species managed to colonize all three borrow pits.

In summary, removal of the surface organic horizons and non-vascular plants during road, borrow pit, and bladed slope construction, has produced significantly warmer and drier substrates (Table 6.3). As a consequence, these sites supported lower bryophyte and lichen plant covers. In contrast, the undisturbed controls and bladed trails had cooler and wetter soil climates, and they contained significantly more abundant non-vascular taxa. The pH of these was neutral (7.0) to slightly acidic (6.5), while the pH of more extreme disturbances was higher (7.8. Soil reaction differences reflected the absence of an LFH horizon and non-vascular taxa, as lichen and bryophyte cover tended to decrease significantly as pH increased.

6.2.3 Relationships Among Disturbance, Habitat and Relative Vegetation Development Characteristics

Comparisons of relative floristic development (i.e. DECORANA Axis scores, Appendix VIII) with the disturbance regime variables were made using Kendall's Rank-Order Correlation Coefficient, Tau (Table 6.6). The results of this analysis were similar to those of species abundances.

It is important to note that the ordination scores for the undisturbed controls tended to be low on both axes, while the Stream Bed control was highest. Intensity, severity (shrub destruction), and terrain sensitivity had significant and positive correlations with axis one and axis two scores. These correlations indicated that, as disturbance magnitude and terrain

Table 6.6: Kendall's Rank-Order Correlations Between DECORANA Axis Scores and Disturbance Regime Variables (n=12) Milepost 40, Dodo Valley, N.W.T.

	Disturbance Regime Variables[3]					
Axis[1]	Intensity	Spatial Extent (m^2)	Perimeter: Area	Terrain Sensitivity	% Shrub Destruction	Microtopographical Change
1	0.63[a][2]	-0.36	0.23	0.56[a]	0.64[a]	0.39
2	0.72[a]	-0.36	0.17	0.56[a]	0.64[a]	0.42

[1] Refer to Figure 5.2 and Appendix 9 for Axis score values.

[2] Association values (Tau) followed by the letter "a" indicates significant ($p < 0.05$) association.

[3] Refer to Section 4.2.1 for discussion of disturbance regime variables.

sensitivity increased, relative floristic development tended to decrease. Furthermore, these relationships were evident even 40 years following the disturbances. Spatial extent, perimeter:area, and microtopographical change were not significantly correlated with either axis one or axis two scores.

Floristic differences between undisturbed control and CANOL disturbance stands were significantly ($p<0.05$) correlated with differences in soil climate, pH, and organic matter content (Table 6.7). More specifically, the axis scores tended to be greater in stands which had relatively high soil temperatures and pH values, and comparatively low soil moisture and organic matter. This included the road, borrow pits, and bladed slopes.

6.2.4 Comparisons of Vegetation Characteristics on Sites Classified According to Disturbance Intensity

The previous analyses have indicated that disturbance, habitat, non-vascular growth form cover values, and relative floristic development were all correlated. Generally, as disturbance intensity increased:

1) soil moisture and organic matter decreased;
2) soil temperature and pH increased;
3) non-vascular plant cover was lower; and
4) relative floristic development declined.

Interpretations of the statisical tests indicate that habitat was still strongly linked with disturbance characteristics. It is apparent from this result that attempts to distinguish possible habitat effects on plant community development from disturbance effects are questionable. This relationship may dissipate with time, but after 40 years, habitat still appeared to be an indirect expression of disturbance magnitude. In light of this conclusion, only disturbance characteristics were used for subsequent statistical tests.

Growth form covers were compared among sites from undisturbed control and disturbances of extreme and moderate intensity, using Mann-Whitney U Tests (Sokal and Rohlf 1981). Disturbances of moderate intensity, the three bladed trails, differed significantly

Table 6.7: Spearman's Rank-Order Correlation Coefficients Between DECORANA Axis Scores and Abiotic Variables (n=43) Milepost 40, Dodo Valley, N.W.T.

Axis[1]	Soil Temperature (°C at -10cm)	Soil Moisture (% at -10cm)	pH (DD H_2O)
1	0.80[2a]	-0.74[a]	0.65[a]
2	0.69[a]	-0.62[a]	0.62[a]

1. Refer to Figure 5.2 and Appendix 9 for this axis score values.

2. Association values (Rho) followed by the letter "a" indicates significant ($p < 0.01$) association.

Table 6.8: Long Term (40 Years) Response of Growth Form Cover (%) to Disturbances of Different Intensity

Milepost 40, Dodo Valley, N.W.T.

Intensity	Growth Form Cover (%)							
	Total	Tree	Shrub	Forb	Graminoid	Moss	Lichen	Non-Vascular
6[2]	93.2±14.1a	3.0±1.7c	31.0±5.1d	4.4±1.9	10.0±5.2	36.6±10.7	8.8±4.8	45.3±13.4
8 - 10[3]	56.8±11.8	5.4±2.4bc	44.7±11.7d	2.5±1.8e	1.8±1.6f	2.2±1.4g	0.3±0.4h	2.5±1.8i
Control[4]	81.9±13.3a	6.0±1.8b	23.7±2.1	2.7±1.4e	4.4±1.4f	32.7±10.6	12.3±3.7	44.9±12.8

1. Adapted from Higginbottom (1974); see Section 3.4.3, Appendix 2.

2. Telephone Line, Minor and Major Rights-of-Way.

3. Bladed Slopes (intensity = 8), Borrow Pits (9), Road (10).

4. East Talus Control; West Terrace Control.

5. Down column values are means ± 95% confidence limits; common letters indicate means that are not significantly ($p < 0.05$) different according to the Mann-Whitney U Test.

($p<0.05$) in four vegetation categories from the undisturbed controls. Tree cover was significantly lower on the bladed trails, while shrub cover was higher. In addition, both herbaceous categories, forb and graminoid, also had increased their plant cover significantly over 40 years, relative to the controls. Overall, there was no difference in total plant cover between undisturbed controls and disturbances of moderate intensity. The bladed trails' floras represented typical examples of a shift in growth form abundances in response to disturbance.

Six of the eight growth form categories differed significantly between disturbances of extreme intensity with those of the undisturbed controls. Total cover was on average 25% lower on the disturbances. In fact, only shrubs at 44.7% achieved higher covers than on the controls (23%). This was attributable to one species, ***Dryas drummondii***. Graminoids, mosses, lichens, and non-vasculars were all significantly lower on the extreme disturbances (Table 6.8). Although tree cover was statistically the same, the species contributing the bulk of the cover on sites from these two disturbance classes were different. ***Populus balsamifera*** was clearly the most abundant disturbance species, while ***Picea glauca, Picea mariana,*** and ***Larix laricina*** dominated the controls. Overall, the response was not as much a shift in plant species abundances but a reduction in cover.

A comparison of disturbances of moderate intensity with those rated as extreme also revealed some differences. Total plant and all non-woody vegetation categories had significantly ($p<0.05$) higher covers on the bladed trails. Mean total cover was almost 40% greater on the bladed trails. This was primarily due to greater graminoid and non-vascular plant species covers (Table 6.8).

Several factors seem to account for the higher plant cover on the bladed trails when compared to the road, borrow pits and bladed slopes. Many bladed trail plants, such as the non-vasculars, survived the disturbances intact, while graminoids and shrubs resprouted. Vegetative and sexual (i.e. seed) reproduction may have assisted in the bladed trails' recovery as well. Contrarily, no or few plants survived the higher magnitude perturbations. Plant community development on the road, bladed slopes and in the borrow pits was, therefore, dependent entirely on plant colonization from off-site sources.

Long-term disturbance-induced habitat alterations on the bladed trails were relatively small, and thus, most pre-disturbance plant species were capable of growing there. In contrast, the habitats on the extreme disturbances, differed markedly from adjacent controls and the bladed trails. Many plant taxa were either not capable of colonizing these sites (e.g. feathermosses) or proliferating on them (e.g. *Ledum groenlandicum*).

Tests for significant differences among the axis one and two scores of the undisturbed controls and sites affected by moderate and extreme disturbances, were performed using Mann-Whitney U Two Sample comparisons (Sokal and Rohlf 1981) (Table 6.9). The results mirrored those of the abundance data analyses (Table 6.8). The axis scores of moderate disturbances, the bladed trails, were statisticaly indistinguishable from the undisturbed controls. In terms of relative floristic development, the Telephone, Minor, and Major Rights-of-Way had recovered. More intense disturbances were located in the borrow pits and on the bladed slopes and road. Both sets of axis scores were significantly greater than the undisturbed controls and the bladed trails, and, as a consequence, these disturbances had remained in a damaged condition. In other words, their relative floristic development was less complete than that of the bladed trails and undisturbed controls. This was due to fewer and perhaps more imporantly, less abundant species.

Table 6.9: Mann-Whitney U Two Sample Comparison of DECORANA Axis Scores Among Controls and Disturbances of Moderate (6) and Extreme 8-10) Intensity (n=43) Milepost 40, Dodo Valley, N.W.T.

Disturbance Intensity[1]	Axis 1 Score[2]	Axis 2 Score
6[3]	63.3 ± 25.0[a6]	83.2 ±46.5[b]
8[4]	187.6 ± 78.3	187.6 +28.8
Control[5]	76.1 ±26.2[a]	62.5 ± 17.3[b]

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[1] Adapted from Heginbottom 1973; see Section 3.4.3, Appendix 2.

[2] Refer to Figure 5.2 and Appendix 9 for Axis score values.

[3] Telephone, Minor, and Major Rights-of-Way.

[4] Bladed Slopes (intensity=8), Borrow Pits (9), Road (10).

[5] East Talus and West Terrace Controls.

[6] Means ± 95% confidence limits; common letters indicate means that are not significantly ($p < 0.05$) different.

7. CONCLUSION

The long-term natural revegetation of nine CANOL No. 1 Project disturbances was investigated in Dodo Valley, N.W.T. Three borrow pits, two bladed slopes, one road and three bladed trails were studied. Analyses of floristic and physiognomic data revealed variable long-term responses to the perturbations, as each disturbed plant community contained examples of recovery, enhancement and degradation.

All plant species present on the disturbances at Milepost 40 also occurred in the controls. The localized increase in species diversity observed by Kershaw (1983) for alpine areas along the CANOL Project either did not occur or was relatively short-lived (< 40 years). It appears that there was no species replacement sequence on any disturbance, but merely a shift in species abundances. This type of floristic response has been reported elsewhere throughout the Subarctic and Arctic, where many of its component plant species are adapted to a relatively wide range of growth conditions (Wein and El-Bayoumi 1983). Another noteworthy florsitic response was the absence or rarity of non-vascular plant taxa on the more extremely perturbed sites.

7.1 Revegetation on Disturbances

Bladed Trails

The Telephone, Minor and Major Rights-of-Way plant communities had recovered in most respects. Differences in species composition among the bladed trail and undisturbed control plant communities were relatively small. Resprouting of undamaged rootstocks and minimal invasion by seed propagules were probably the primary reasons for the development of similar floras on these sites (Reid and Janz 1974, Riewe 1979, Viereck et al. 1979, Yarie 1983). Evidence of site enhancement was characterized by slight increases in species equitability and species richness, and more abundant shrub, graminoid and forb growth forms. Increases in understory plant covers relative to the controls may have reflected higher radiation input, warmer soil temperatures and greater nutrient availability (Van Cleve and Dyrness 1983, Grime and Anderson 1986). This process may have occurred relatively quickly, as well. Species which have frequently reestablished or exceeded predisturbance levels on two-to-five year old seismic lines in the Subarctic such as *Alnus crispa, Salix* spp., *Ledum groenlandicum, Arctostaphylos rubra, Betula glandulosa, Vaccinium uliginosum* and *Rhododendron lapponicum* (Hettinger 1973, Hernandez 1974b, Reid 1974, Riewe 1977) were also common on the CANOL Disturbance sites. An absent or sparse tree layer on the bladed trails was the only feature which could be classified as degraded. The dominance of understory plant species may have inhibited tree regeneration (Hernandez 1973, Wein and El-Bayoumi 1983). *Picea glauca* was present in the understory on all three bladed trails, however. Without further disturbance, the tree stratum should eventually re-establish itself (Viereck 1975).

Plant community recovery on the remaining six disturbances was less complete. Compared to the undisturbed controls, the road, bladed slope and borrow pit perturbations possessed fewer characteristics which could be described as enhanced or even recovered. On the basis of simpler physiognomic and species structures, the vegetation on the these sites was considered not fully recovered.

Road

The Road plant community was in the most degraded condition, with a physiognomc and floristic structure comparable to nearby intermittent stream beds. The dominance of broad-leaf shrub and deciduous tree species on this CANOL perturbation was not surprising. *Dryas drummondii, D. integrifolia, Equisetum arvense, Epilobium angustifolium, Potentilla fruticosa, Alnus crispa, Populus balsamifera* and *Salix* spp. which were important and persistent colonizers on the Road, frequently comprise a substantial portion of the intitial flora on gravel sites throughout the Subarctic (Hettinger 1973, Hernandez 1974 a and b, Reid 1974, Grime and Anderson 1986). The dominance of these same species on the Road after 40 years suggests there probably has been relatively little change in the Road's floristic character since the establishment of its initial post-disturbance plant community. Changes in physiognomic structure appear to be occurring, however. Although few *Picea glauca* individuals were present in the Road's sparse tree layer their seedling densities exceeded control values. This indicates that restoration of the ***P. glauca*** canopy should eventually take place on this site.

Borrow Pits

An overall assessment of the shrub-dominated Borrow Pit plant communities indicated they also were in a damaged state, although recovery had been more complete than on the Road. The rafting of plants and topsoil into the pits appeared to be the major reason for the difference. The presence of several species, particularily lichens such as *Cladina mitis,* was probably entirely a product of this revegetation by mass immigration process. There were no lichens on the Road. Rafting may have also caused the borrow pits to have a greater floristic affinity with the East Talus Control, where they were situated, than the West Terrace Control. In fact, Borrow Pit F and East Talus stands were members of the same TWINSPAN cluster (Figure 5.1). The Borrow Pits also had species densities comparable to both undisturbed controls. Traits which characterized less-developed borrow pit vegetation were lower species' equitability and abundance, as well as a simpler physiognomic structure.

Bladed Slopes

The two Bladed Slopes had not fully recovered in the 40 years since disturbance. These sites were dominated by relatively few species, most notably the evergreen shrubs *Dryas drummondii* and *D. integrifolia*. Consequently, equitability and plant cover were lower, and physiognomic structure simpler when compared to the undisturbed controls. All of the Borrow Pit and Bladed Slope sites contained immature *Picea glauca* trees, indicating restoration of a conifer dominated tree layer.

7.2 Relationships Among Disturbance, Habitat and Vegetation Characteristics

Plant community recovery reflected direct and indirect influences of the disturbances. The former operated through varying degrees of plant destruction, while the latter acted by modifying soil properties. Terrain sensitivity, disturbance intensity and one severity descriptor, shrub destruction, were all correlated with plant species abundance. They were also significantly correlated with each other, suggesting an interdependence.

Generally, these three disturbance variables produced strong, negative correlations with total, bryophyte and lichen plant covers. The DECORANA Axis scores had strong, positive correlations with these variables, thus suggesting that relative floristic development over the long-term tended to be lower following more intense disturbances. Similar situations have been reported following disturbances throughout the North, although disturbance-induced changes in habitat were considered the chief cause (Gill 1973a and 1973b, Heginbottom 1973, Bell et al. 1974, Peterman 1980, Vitousek and White 1981).

The results of the Dodo Valley research also indicated a strong correlation between disturbance and habitat characteristics. Generally, the greater the disturbance magnitude, the less a soil resembled those of the undisturbed sites: soils tended to be warmer and drier, had shallower LFH horizons, less % organic matter and higher surface pH's. Plant species abundance and the DECORANA Axis scores were correlated with these soil properties. Soil temperature and soil moisture may have been the two most important properties affecting revegetation, as they produced the largest correlation coefficients. Although correlation does not invariably imply causation, these two habitat conditions purportedly do control plant community development, at least in the early stages (Mikola 1970, Gill 1973a, Strang 1973, Viereck et al. 1983, Grime and Anderson 1986). Soil temperature, soil moisture and to a lesser extent, soil chemistry, regulate reproductive and nutrient turnover rates, and influence seed germination and establishment success (Viereck et al. 1983).

Total non-vascular cover may have been the key factor governing the relationships among the floristic and soils properties at Milepost 40. Bladed trail sites, which sustained only partial destruction of the non-vascular plant stratum and LFH layer had, 40 years following the perturbations, abundant bryophyte and lichen plant covers. Their soil climates and other soil properties such as pH, were similar to undisturbed controls. The Road, Borrow Pit and Bladed Slope sites which had relatively warm and dry soils, supported sparse bryophyte and lichen covers.

Overall, long-term responses of the Subarctic woodland vegetation at Milepost 40, Dodo Valley, N.W.T. to CANOL perturbations were related to disturbance magnitude and associated habitat modifications. Although floristic responses were variable, the presence of *Picea glauca* on all disturbances indicated restoration of woodland vegetation. Thus, only two hypotheses, both predicting recovery, could be supported by the data collected from the study area:

1) Recovery;

2) Recovery with new characteristics.

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APPENDIX I: TERRAIN DISTURBANCE SUSCEPTIBILITY

Terrain Disturbance Susceptibility[1]

Susceptibility Rank	Terrain Description	Terrain Susceptibility and Predicted Responses to Disturbance
1.	Bedrock with low ice content.	No changes caused by disturbance except steep slopes of frozen shale.
2.	Silt to gravelly testured material on level (< 5°) terrain; boreal ice lenses.	Minor ground-ice slumping, gullying and/or thermokarst subsidence.
3.	Moderately to highly ice-rich clayey to loamy textured material with discontinuous organic cover.	Low to moderate susceptibility to gullying and ground-ice slumping.
4.	Moisture/ice-rich and highly compressible peat soils, or moderately ice-rich clayey to silty till on steeply (> 5°) sloping terrain.	Moderate to high susceptibility to thermokarst subsidence, gullying and ground-ice slumping.
5.	Highly plastic inorganic clay, clayey silt, and organic soils; with moderate to high ice content on slopes < 5°.	Susceptible to major thermokarsting and rapid gullying.
6.	Highly plastic inorganic clay, clayey silt, and organic soils; with moderate to high ice content on slopes > 5°.	Susceptible to major thermokarsting, rapid gullying, and land slides.

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1. Modified from Kurfurst (1973).

APPENDIX II: RANKINGS OF DISTURBANCE INTENSITY

Appendix II : Ranking of Disturbing Agents and Processes in Terms of the Intensity of Their Initial Impact

Dodo Valley, N.W.T.

Rank	Intensity	Agent	Process/Severity
1.	Least Intensive	Single to few passes of man on foot.	Minor compaction.
2.		Removal of trees by hand.	Minor vegetation removal.
3.		Single to few passes with vehicle (with minimal removal of vegetation).	Minor to medium compaction; minor mechanical damage and minor vegetation removal.
4.		Forest fire.	Vegetation destruction.
5.		Multiple passes of man on foot.	Medium compaction and minor mechanical damage.
6.		Shallow bulldozing.	Vegetation and soil removal, compaction.
7.		Multiple passes of vehicles with shallow bulldozing.	Severe compaction, vegetation removal, and severe mechanical damage, soil removal.
8.		Moderately deep bulldozing (Borrow Pit construction).	Complete vegetation destruction, moderate soil removal, compaction.
9.		Deep bulldozing (Borrow Pit construction).	Complete vegetation removal, severe soil excavation, compaction.
10.	Most Intensive	Deep bulldozing, dumping and compaction (road construction).	Complete vegetation removal, complete soil excavation or burial, severe substrate compaction.

Adapted from Heginbottom 1973

APPENDIX III: AGES OF WOODY PLANT SAMPLES

Mean Tree/Shrub Ages Listed by Site and Species

Dodo Valley, N.W.T.

Tree Species	East Control	West Control	Borrow Pit A	Borrow Pit B	Borrow Pit F	Bladed Slope D	Road	Telephone R.O.W.	Minor R.O.W.	Major R.O.W.
Larix laricina	36 27*	54 7	-	-	39 2	-	-	33 6	42 3	-
Picea glauca	103 28	182 43	39 2	71 2	112 2	26 1	28 6	69 18	64 6	55 3
Picea mariana	88 3	101 25	-	-	-	-	-	55 11	28 1	-
Populus balsamifera	-	-	22 2	16 1	29 2	28 2	27 6	-	-	-
Shrub Species										
Alnus crispa	49.3 4	42 3	-	66 1	-	33 1	29 3	55 2	27 4	17 2
Betula glandulosa	66.5 4	45 6	46 1	39 1	37 1	25 1	31 3	52 6	36 2	30 2
Potentilla fruticosa	46.4 7	37.6 10	37 1	21 1	14 1	29 1	28 4	49 6	41 5	31 3
Salix alaxensis	45 5	50 8	34 1	27 1	31 1	28 1	32 2	32 4	26 4	37 2
Salix arbusculoides	-	59 2	-	-	25 1	31 1	30 2	46 3	22 5	25 2
Shepherdia canadensis	40 2	29 8	29 1	18 1	24 1	26 1	22 5	20 3	27 2	-

* Numbers on the bottom indicate the sample size (n).

Maximum Tree/Shrub Ages Listed by Site and Species

Dodo Valley, N.W.T.

Species	East Control	West Control	Borrow Pit A	Borrow Pit B	Borrow Pit F	Bladed Slope D	Road	Telephone R.O.W.	Minor R.O.W.	Major R.O.W.	Max. Age
Alnus crispa	90	70	-	66	-	33	36	76	34	17	90
Betula glandulosa	84	59	46	39	37	-	40	79	41	30	84
Larix laricina	58	72	-	-	62	-	-	39	40	-	72
Picea glauca	183	401	42	85	115	26	30	144	129	57	401
Picea mariana	128	195	-	-	-	-	-	109	28	-	195
Potentilla fruticosa	73	74	37	21	14	29	32	74	63	34	74
Salix alaxensis	97	78	34	27	31	28	33	37	30	50	97
Salix arbusculoides	-	79	-	-	25	-	-	60	31	29	79
Shepherdia canadensis	68	35	29	18	24	26	19	51	26	28	68
Populus balsamifera	-	-	25	16	30	29	36	-	-	-	36
Maximum Age	183	401	46	85	115	33	40	144	129	57	

Percentages of Samples on Disturbances Pre-dating 1942

Dodo Valley, N.W.T.

Disturbance	Sample	Total n	No. Samples Pre-dating 1942	% Samples Pre-dating 1942
Borrow Pit A	Trees	4	0	0
	Shrubs	4	1	25
	Trees &Shrubs	8	1	12.5
Borrow Pit B	Trees	3	2	67
	Shrubs	5	2	40
	Trees & Shrubs	8	4	50
Borrow Pit F	Trees	6	3	50
	Shrubs	5	0	0
	Trees & Shrubs	11	3	27
Bladed Slope D	Trees	3	0	0
	Shrubs	5	0	0
	Trees & Shrubs	8	0	0
Road	Trees	12	0	0
	Shrubs	15	0	0
	Trees & Shrubs	27	0	0
Telephone Line R.O.W.	Trees	35	20	57
	Shrubs	26	12	46
	Trees & Shrubs	61	32	53
Minor R.O.W.	Trees	10	4	40
	Shrubs	25	2	8
	Trees & Shrubs	35	6	17
Major R.O.W.	Trees	3	3	100
	Shrubs	13	1	8
	Trees & Shrubs	16	4	25

APPENDIX IV: CONTROL PLANT COMMUNITY FLORAS

EAST TALUS

Picea glauca/ Dryas integrifolia/ Carex scirpoidea/ Cladina mitis CONTROL

SPECIES	N	FREQ	COV	SPECIES	N	FREQ	COV
TREES							
Larix laricina	70	31.42	0.78	Picea glauca	70	90.00	3.90
Picea mariana	70	15.71	2.24	Populus balsamifera	70	1.42	0.02
SHRUBS							
Alnus crispa	70	10.00	0.65	Andromeda polifolia	70	68.57	0.29
Arctostaphylos rubra	70	91.42	1.34	Arctostaphylos uva-ursi	70	81.42	3.12
Betula glandulosa	70	77.14	3.32	Betula occidentalis	70	7.14	0.22
Cassiope tetragona	70	5.71	0.02	Dryas drummondii	70	7.14	0.02
Dryas integrifolia	70	97.14	6.86	Empetrum nigrum	70	45.71	0.34
Juniperus communis	70	71.42	0.43	Juniperus horizontalis	70	2.85	0.05
Ledum decumbens	70	1.42	0.01	Ledum groenlandicum	70	67.14	0.45
Linnaea borealis	70	51.42	0.34	Potentilla fruticosa	70	92.85	1.18
Rhododendron lapponicum	70	84.28	0.91	Salix alaxensis	70	8.57	0.22
Salix arbusculoides	70	4.28	0.08	Salix bebbiana	70	10.00	0.07
Salix brachycarpa	70	4.28	0.02	Salix glauca	70	1.42	0.01
Salix myrtillifolia	70	17.14	0.13	Salix reticulata	70	4.28	0.015
Shepherdia canadensis	70	14.28	0.05	Vaccinium uliginosum	70	65.71	0.99
Vaccinium vitis-idaea	70	40.00	0.29	Rosa acicularis	70	1.42	0.01
HERBS							
Androsace chamaejasme	70	58.57	0.08	Anemone parviflora	70	85.71	0.28
Campanula aurita	70	8.57	0.01	Castilleja caudata	70	4.28	0.01
Centernnaria friesianna	70	15.71	0.05	Cypripedium calceolus	70	8.57	0.01
Cypripedium passerinum	70	27.14	0.11	Erigeron hyssopifolius	70	1.42	0.01
Epilobium angustifolium	70	1.42	0.01	Epilobium latifolium	70	2.85	0.01
Erigeron pumilus	70	5.71	0.02	Galium boreale	70	8.57	0.03
Geocaulon lividum	70	5.71	0.03	Gentiana prostrata	70	5.71	0.01
Hedysarum alpinum	70	31.42	0.23	Hedysarum boreale	70	5.71	0.03
Lesquerella arctica	70	1.42	0.01	Oxytropis campestris	70	2.85	0.02
Papaver macounii	70	1.42	0.01	Pedicularis labradorica	70	31.42	0.04
Pedicularis sudetica	70	1.42	0.01	Pinguicula vulgaris	70	10.00	0.01
Planthanera hyperborea	70	2.85	0.01	Pyrola asarifolia	70	2.85	0.01
Pyrola chlorantha	70	24.28	0.04	Pyrola secunda	70	5.71	0.01
Rumex arcticus	70	1.42	0.01	Saussurea angustifolia	70	5.71	0.01
Saxifraga aizoides	70	2.85	0.01	Saxifraga oppositifolia	70	4.28	0.01
Senecio atropupureus	70	1.42	0.01	Senecio lugens	70	14.28	0.01
Polygonum viviparum	70	7.14	0.01	Thalictrum alpinum	70	54.28	0.13
Tofieldia pusilla	70	54.28	0.13	Tofieldia coccinea	70	5.71	0.01
Woodsia ilvensis	70	5.71	0.01	Zygadenus elegans	70	38.57	0.11
Equisetum arvense	70	15.71	0.06	Equisetum palustre	70	5.71	0.01
Equisetum scirpoides	70	5.71	0.02	Selaginella selaginoides	70	5.71	0.01
Parrya nudicaulis	70	35.71	0.04	Parnassia palustris	70	12.85	0.01
GRAMINOIDS							
Agropyron violaceum	70	5.71	0.05	Arctagrostis latifolia	70	1.42	0.02
Calamagrostis neglecta	70	27.14	0.23	Calamagrostis purpurascens	70	1.42	0.01

Carex eburnea	70	2.85	0.01	Carex microglochin	70	1.42	0.04
Carex scirpoidea	70	87.14	1.85	Carex vaginata	70	11.42	0.08
Elymus innovatus	70	54.28	0.81	Festuca altaica	70	40.00	0.31
Puccinellia deschampsiodes	70	1.42	0.05	Trisetum spicatum	70	1.42	0.01
LICHENS							
Cetraria cucullata	70	60.00	0.51	Cetraria islandica	70	62.85	1.17
Cetraria nivalis	70	31.42	0.78	Cladina mitis	70	82.85	6.76
Cladina rangiferina	70	14.28	0.28	Cladonia stellaris	70	7.14	0.45
Cladonia amaurocraea	70	2.85	0.01	Cladonia gracilis	70	4.28	0.01
Cladonia verticillata	70	7.14	0.01	Cladonia sp.	70	1.42	0.01
Dactylina arctica	70	1.42	0.01	Evernia mesomorpha	70	28.57	0.38
Peltigera apthosa	70	2.85	0.01				
BRYOPHYTES							
Aulacomnium acuminatum	70	4.28	0.07	Brachythecium salebrosum	70	2.85	0.11
Campylium stellatum	70	1.42	0.02	Dicranum groenlandicum	70	11.42	0.05
Ditrichum flexicaule	70	4.28	0.02	Drepanocladus uncinatus	70	27.14	0.82
Hylocomium splendens	70	32.85	2.81	Hypnum bambergii	70	24.28	0.70
Pleurozium schreberi	70	21.42	0.20	Thuidium abietinum	70	50.00	0.56
Tortella sp.	70	14.28	0.04	Rhytidium rugosum	70	42.85	1.41
Ptilidium ciliare	70	10.00	0.06				

EAST TALUS

Picea glauca/ Dryas integrifolia/Carex scirpoidea/Cladina mitis CONTROL

SPECIES	N	FREQ	COV	SPECIES	N	FREQ	COV
TREES							
Larix laricina	70	31.42	0.78	Picea glauca	70	90.00	3.90
Picea mariana	70	15.71	2.24	Populus balsamifera	70	1.42	0.02
SHRUBS							
Alnus crispa	70	10.00	0.65	Andromeda polifolia	70	68.57	0.29
Arctostaphylos rubra	70	91.42	1.34	Arctostaphylos uva-ursi	70	81.42	3.12
Betula glandulosa	70	77.14	3.32	Betula occidentalis	70	7.14	0.22
Cassiope tetragona	70	5.71	0.02	Dryas drummondii	70	7.14	0.02
Dryas integrifolia	70	97.14	6.86	Empetrum nigrum	70	45.71	0.34
Juniperus communis	70	71.42	0.43	Juniperus horizontalis	70	2.85	0.05
Ledum decumbens	70	1.42	0.01	Ledum groenlandicum	70	67.14	0.45
Linnaea borealis	70	51.42	0.34	Potentilla fruticosa	70	92.85	1.18
Rhododendron lapponicum	70	84.28	0.91	Salix alaxensis	70	8.57	0.22
Salix arbusculoides	70	4.28	0.08	Salix bebbiana	70	10.00	0.07
Salix brachycarpa	70	4.28	0.02	Salix glauca	70	1.42	0.01
Salix myrtillifolia	70	17.14	0.13	Salix reticulata	70	4.28	0.015
Shepherdia canadensis	70	14.28	0.05	Vaccinium uliginosum	70	65.71	0.99
Vaccinium vitis-idaea	70	40.00	0.29	Rosa acicularis	70	1.42	0.01
HERBS							
Androsace chamaejasme	70	58.57	0.08	Anemone parviflora	70	85.71	0.28
Campanula aurita	70	8.57	0.01	Castilleja caudata	70	4.28	0.01
Centernnaria friesianna	70	15.71	0.05	Cypripedium calceolus	70	8.57	0.01
Cypripedium passerinum	70	27.14	0.11	Erigeron hyssopifolius	70	1.42	0.01
Epilobium angustifolium	70	1.42	0.01	Epilobium latifolium	70	2.85	0.01
Erigeron pumilus	70	5.71	0.02	Galium boreale	70	8.57	0.03
Geocaulon lividum	70	5.71	0.03	Gentiana prostrata	70	5.71	0.01
Hedysarum alpinum	70	31.42	0.23	Hedysarum boreale	70	5.71	0.03
Lesquerella arctica	70	1.42	0.01	Oxytropis campestris	70	2.85	0.02
Papaver macounii	70	1.42	0.01	Pedicularis labradorica	70	31.42	0.04
Pedicularis sudetica	70	1.42	0.01	Pinguicula vulgaris	70	10.00	0.01
Planthanera hyperborea	70	2.85	0.01	Pyrola asarifolia	70	2.85	0.01
Pyrola chlorantha	70	24.28	0.04	Pyrola secunda	70	5.71	0.01
Rumex arcticus	70	1.42	0.01	Saussurea angustifolia	70	5.71	0.01
Saxifraga aizoides	70	2.85	0.01	Saxifraga oppositifolia	70	4.28	0.01
Senecio atropupureus	70	1.42	0.01	Senecio lugens	70	14.28	0.01
Polygonum viviparum	70	7.14	0.01	Thalictrum alpinum	70	54.28	0.13
Tofieldia pusilla	70	54.28	0.13	Tofieldia coccinea	70	5.71	0.01
Woodsia ilvensis	70	5.71	0.01	Zygadenus elegans	70	38.57	0.11
Equisetum arvense	70	15.71	0.06	Equisetum palustre	70	5.71	0.01
Equisetum scirpoides	70	5.71	0.02	Selaginella selaginoides	70	5.71	0.01
Parrya nudicaulis	70	35.71	0.04	Parnassia palustris	70	12.85	0.01
GRAMINOIDS							
Agropyron violaceum	70	5.71	0.05	Arctagrostis latifolia	70	1.42	0.02
Calamagrostis neglecta	70	27.14	0.23	Calamagrostis purpurascens	70	1.42	0.01

Elymus innovatus	58	24.13	0.14	*Festuca altaica*	58	77.58	1.82
LICHENS							
Cetraria cucullata	58	25.86	0.20	*Cetraria islandica*	58	20.69	0.31
Cetraria nivalis	58	12.06	0.06	*Cladina mitis*	58	74.13	15.19
Cladonia stellaris	58	3.44	0.06	*Cladonia amaurocraea*	58	5.17	0.06
Cladonia coccifera	58	12.06	0.12	*Cladonia gracilis*	58	27.58	0.32
Cladonia multiformis	58	1.72	0.01	*Cladonia pyxidata*	58	1.72	0.01
Dactylina arctica	58	1.72	0.01	*Evernia mesomorpha*	58	1.72	0.01
Peltigera apthosa	58	34.48	0.26				
BRYOPHYTES							
Aulacomnium acuminatum	58	31.03	0.81	*Brachythecium salebrosum*	58	6.89	0.17
Campylium stellatum	58	10.34	0.35	*Dicranum groenlandicum*	58	32.75	1.01
Ditrichum flexicaule	58	15.51	0.55	*Drepanocladus revolvens*	58	1.72	0.17
Drepanocladus uncinatus	58	24.13	1.08	*Hylocomium splendens*	58	63.79	24.23
Hypnum bambergii	58	20.69	1.37	*Plagiomnium ellipticum*	58	34.48	2.96
Pleurozium schreberi	58	37.93	4.86	*Sphagnum fuscum*	58	3.44	0.89
Sphagnum rubellum	58	1.72	0.10	*Thuidium abietinum*	58	22.41	1.01
Rhytidium rugosum	58	74.13	6.04	*Ptilidium ciliare*	58	15.51	1.01

WEST (LOWER TERRACE)

Picea glauca/ Ledum groenlandicum/ Festuca altaica/ Hylocomium splendens CONTROL

SPECIES	N	FREQ	COV	*SPECIES*	N	FREQ	COV
TREES							
Picea glauca	60	98.33	4.24	*Picea mariana*	60	1.66	0.01
Populus tremuloides	60	3.33	0.01				
SHRUBS							
Alnus crispa	60	18.33	1.06	*Andromeda polifolia*	60	30.00	0.09
Arctostaphylos rubra	60	85.00	2.55	*Arctostaphylos uva-ursi*	60	40.00	0.40
Betula glandulosa	60	73.33	2.68	*Betula occidentalis*	60	5.00	0.05
Cassiope tetragona	60	1.66	0.01	*Dryas drummondii*	60	1.66	0.01
Dryas integrifolia	60	61.66	1.43	*Empetrum nigrum*	60	48.33	0.47
Juniperus communis	60	31.66	0.16	*Ledum decumbens*	60	1.66	0.06
Ledum groenlandicum	60	98.33	4.20	*Linnaea borealis*	60	61.66	0.57
Oxycoccus microcarpus	60	1.66	0.05	*Potentilla fruticosa*	60	86.66	0.85
Rhododendron lapponicum	60	25.00	0.13	*Salix alaxensis*	60	38.33	0.91
Salix arbusculoides	60	10.00	0.35	*Salix brachycarpa*	60	6.66	0.10
Salix glauca	60	10.00	0.06	*Salix myrtillifolia*	60	51.66	0.73
Salix reticulata	60	13.33	0.21	*Salix scouleriana*	60	1.66	0.01
Shepherdia canadensis	60	23.33	0.28	*Vaccinium uliginosum*	60	91.66	4.03
Vaccinium vitis-idaea	60	85.00	1.73	*Rosa acicularis*	60	8.33	0.11
HERBS							
Androsace chamaejasme	60	5.00	0.01	*Anemone parviflora*	60	45.00	0.16
Antennaria pulcherrima	60	8.33	0.05	*Aster sibiricus*	60	15.00	0.06
Boschniakia rossica	60	1.66	0.01	*Cypripedium calceolus*	60	1.66	0.01
Cypripedium passerinum	60	16.66	0.10	*Erigeron hyssopifolius*	60	8.33	0.03
Epilobium latifolium	60	1.66	0.01	*Geocaulon lividum*	60	40.00	0.21
Gentiana prostrata	60	1.66	0.01	*Goodyera repens*	60	10.00	0.01
Planthanera dilitata	60	3.33	0.01	*Hedysarum alpinum*	60	61.66	0.81
Hedysarum boreale	60	5.00	0.10	*Lupinus arcticus*	60	10.00	0.11
Pedicularis labradorica	60	35.00	0.04	*Pedicularis sudetica*	60	3.33	0.01
Pinguicula vulgaris	60	1.66	0.01	*Planthanera hyperborea*	60	13.33	0.01
Pyrola asarifolia	60	33.33	0.20	*Pyrola secunda*	60	5.00	0.01
Saussurea angustifolia	60	6.66	0.01	*Senecio lugens*	60	10.00	0.02
Stellaria edwardsii	60	1.66	0.01	*Polygonum viviparum*	60	15.00	0.01
Thalictrum alpinum	60	8.33	0.01	*Tofieldia pusilla*	60	21.66	0.01
Zygadenus elegans	60	8.33	0.05	*Equisetum arvense*	60	46.66	2.36
Equisetum palustre	60	8.33	0.18	*Equisetum scirpoides*	60	26.66	0.14
Selaginella selaginoide	60	13.33	0.01	*Parrya nudicaulis*	60	10.00	0.01
Parnassia palustris	60	20.00	0.02				
GRAMINOIDS							
Carex aurea	60	1.66	0.01	*Carex eburnea*	60	6.66	0.05
Carex glacialis	60	35.00	0.30	*Carex membranacea*	60	13.33	1.77
Carex microglochin	60	1.66	0.01	*Carex scirpoidea*	60	65.00	1.05
Carex vaginata	60	33.33	0.35	*Elymus innovatus*	60	58.33	0.69
Festuca altaica	60	86.66	1.54	*Trisetum spicatum*	60	1.66	0.01

LICHENS							
Cetraria cucullata	60	28.33	0.53	*Cetraria islandica*	60	26.66	0.52
Cetraria nivalis	60	16.66	0.12	*Cladina mitis*	60	66.66	10.02
Cladina rangiferina	60	5.00	0.13	*Cladonia stellaris*	60	11.66	1.18
Cladonia amaurocraea	60	16.66	0.26	*Cladonia coccifera*	60	3.33	0.01
Cladonia gracilis	60	21.66	0.09	*Cladonia multiformis*	60	5.00	0.01
Peltigera apthosa	60	21.66	0.30				
BRYOPHYTES							
Aulacomnium acuminatum	60	3.33	0.16	*Brachythecium salebrosum*	60	1.66	0.16
Campylium stellatum	60	20.00	1.20	*Dicranum groenlandicum*	60	43.33	1.18
Ditrichum flexicaule	60	6.66	0.09	*Drepanocladus revolvens*	60	5.00	0.12
Drepanocladus uncinatus	60	20.00	2.03	*Hylocomium splendens*	60	73.33	29.01
Hypnum bambergii	60	20.00	1.15	*Plagiomnium ellipticum*	60	6.66	0.30
Pleurozium schreberi	60	63.33	5.04	*Ptilium crista-castrens*	60	6.66	0.75
Thuidium abietinum	60	21.66	0.44	*Rhytidium rugosum*	60	45.00	2.26

STREAM BED

Populus balsamifera/Dryas drummondii/Epilobium latifolium/Campylium stellatum Control

SPECIES	N	FREQ	COV	SPECIES	N	FREQ	COV
TREES							
Larix laricina	20	5.00	0.01	*Picea glauca*	20	55.00	0.31
Populus balsamifera	20	60.00	0.73				
SHRUBS							
Alnus crispa	20	15.00	0.07	*Arctostaphylos rubra*	20	15.00	0.05
Arctostaphylos uva-ursi	20	10.00	0.03	*Dryas drummondii*	20	100.00	35.30
Dryas integrifolia	20	5.00	0.02	*Empetrum nigrum*	20	10.00	0.07
Juniperus communis	20	5.00	0.01	*Linnaea borealis*	20	15.00	0.05
Potentilla fruticosa	20	15.00	0.03	*Salix alaxensis*	20	60.00	0.75
Salix arbusculoides	20	10.00	0.02	*Salix glauca*	20	5.00	0.01
Salix myrtillifolia	20	5.00	0.01	*Salix scouleriana*	20	5.00	0.05
Shepherdia canadensis	20	25.00	0.37	*Vaccinium vitis-idaea*	20	5.00	0.01
HERBS							
Anemone parviflora	20	15.00	0.02	*Aster sibiricus*	20	25.00	0.05
Cypripedium passerinum	20	10.00	0.01	*Epilobium latifolium*	20	55.00	1.15
Hedysarum alpinum	20	15.00	0.05	*Hedysarum boreale*	20	55.00	0.90
Lesquerella arctica	20	10.00	0.01	*Papaver macounii*	20	10.00	0.01
Planthanera hyperborea	20	5.00	0.01	*Pyrola asarifolia*	20	10.00	0.05
Pyrola secunda	20	10.00	0.02	*Equisetum arvense*	20	5.00	0.01
Equisetum palustre	20	30.00	0.02				
GRAMINOIDS							
Agropyron trachycaulum	20	35.00	0.05	*Calamagrostis purpurascens*	20	25.00	0.08
Carex eburnea	20	10.00	0.05	*Carex glacialis*	20	30.00	0.18
Carex scirpoidea	20	10.00	0.01	*Elymus innovatus*	20	25.00	0.40
Trisetum spicatum	20	85.00	0.89				
BRYOPHYTES							
Aulacomnium acuminatum	20	5.00	0.05	*Bryum sp.*	20	5.00	0.25
Campylium stellatum	20	15.00	0.52	*Ditrichum flexicaule*	20	5.00	0.25
Drepanocladus revolvens	20	10.00	0.12	*Hylocomium splendens*	20	5.00	0.01
Thuidium abietinum	20	10.00	0.03	*Tortella sp.*	20	5.00	0.02

APPENDIX V: CONTROL PLANT COMMUNITY SOILS

SOIL PROFILE: Picea glauca/Dryas integrifolia/Carex scirpoidea--
East Side Undisturbed Control

Eutric Brunisol

Horizon	Depth (cm)	
L-F	29-21	Dark reddish brown (5YR 2.5/2,moist), semi-decomposed organic matter;fibrous abundant fine and medium roots; clear, wavy boundary; 4-10 cm thick; pH 6.7.
H	21-0	Black (10YR 2/1, moist), decomposed organic matter; humic, plentiful fine and medium roots; clear, wavy boundary; 4-42 cm thick; pH 7.3.
Bm	0-31	Dark brown (10YR 3/3, moist) dark gray ish brown (10YR 4/2) loam; fine granular to amorphour; few medium roots; very gravelly; clear smooth boundary; 10-42 cm thick; pH 7.4.
Ckg	31+	Very dark grayish brown (10YR 3/2, moist), clay loam; few, fine, faint mottles very dark gray (10YR 3/1); weak fine blocky to amorphous; excessively gravelly; pH 7.8.

SOIL PROFILE: *Picea glauca*/*Ledum groenlandicum*/*Festuca altaica*/*Hylocomium splendens*

West Undisturbed Control (Upper Terrace)

Orthic Gleysol (Peaty Phase)

Horizon	Depth (cm)	
LFH	24-0	Dark yellow brown (10YR 3/4, moist) to black (5YR 2.5/1, moist) organic matter; litter to humic, abundant large to fine roots; gradual, wavy boundary; 0-4- cm thick; pH 6.6.
Bg	0-34	Dark gray brown (10YR 4/2, moist) clay loam; many, medium distinct mottles very dark gray (10YR 3/1, moist); moderate, medium subangular blocky to amorphous; very few medium roots; slightly stony; gradual, wavy boundary; 23-47 cm thick; pH 7.5.
Ckg	34+	Dary gray brown (10YR 4/2, moist) loam; many medium distinct mottles very dark gray (10YR 3/1, moist); weak, fine granular to amorphous; none; excessively stony; pH 7.8.

SOIL PROFILE: Picea glauca/Ledum groenlandicum/Festuca altaica/
Hylocomium splendens
West Undisturbed Control (Upper Terrace)

Gleyed Cumulic Regosol

Horizon	Depth (cm)	
Ah	0-5	Black (10YR 3/1, moist) decomposed organic matter and loam; humic, abundant fine to medium roots; clear, smooth boundary; 3-6 cm thick; pH 6.5.
Bg_1	15-30	Dark brown (10YR 3/3, moist) loam; common, coarse, faint mottles dark gray brown (2.5YR 4/2, moist); weak, fine, granular to amorphous; few large to medium roots; slightly stony; clear, smooth boundary; 7-25 cm thick; pH 7.7.
Ahk	30-35	Very dark gray (10YR 3/1, moist) decomposed organic matter; humic, plentiful fine roots (dead); clear, smooth boundary; 2-11 cm thick; pH 7.3.
Ck	35+	Dark gray brown (10YR 4/2, moist) loamy sand; amorphous; none; excessively stony; pH 7.8.

SOIL PROFILE: *Picea glauca*/*Ledum groenlandicum*/*Festuca altaica*/ *Hylocomium splendens*

West Undisturbed Control (Lower Terrace)

Eutric Brunisol

Horizon	Depth (cm)	
LF	15-0	Black (10YR 2/1, moist) semi-decomposed organic matter; mesic, abundant medium to fine roots, mycorrhiza; gradual, wavy boundary; 10-20 cm thick; pH 4.5.
Bg-C	15+	Very dark gray brown (10YR 3/2, moist) loamy sand; weak, medium granular; few medium to fine roots; excessively stony; pH 7.7.

APPENDIX VI: DISTURBANCE PLANT COMMUNITY FLORAS

BORROW PIT A

SPECIES	N	FREQ	COV	SPECIES	N	FREQ	COV
TREES							
Larix laricina	8	12.50	0.01	*Picea glauca*	8	12.50	0.12
Picea mariana	8	12.50	1.25	*Populus balsamifera*	8	25.00	0.18
SHRUBS							
Alnus crispa	8	12.50	0.06	*Andromeda polifolia*	8	62.50	0.25
Arctostaphylos rubra	8	75.00	1.37	*Arctostaphylos uva-ursi*	8	62.50	3.01
Betula glandulosa	8	87.50	2.31	*Dryas integrifolia*	8	100.00	7.93
Empetrum nigrum	8	25.00	0.01	*Juniperus communis*	8	37.50	0.13
Ledum groenlandicum	8	50.00	0.13	*Linnaea borealis*	8	50.00	0.25
Potentilla fruticosa	8	100.00	2.43	*Rhododendron lapponicum*	8	87.50	1.01
Salix alaxensis	8	75.00	5.87	*Salix arbusculoides*	8	75.00	3.31
Salix brachycarpa	8	25.00	0.01	*Salix myrtillifolia*	8	50.00	0.26
Salix reticulata	8	25.00	0.07	*Shepherdia canadensis*	8	12.50	0.06
Vaccinium uliginosum	8	62.50	0.31				
HERBS							
Androsace chamaejasme	8	62.50	0.06	*Anemone parviflora*	8	50.00	0.26
Antennaria pulcherrima	8	12.50	0.01	*Castilleja caudata*	8	12.50	0.01
Epilobium latifolium	8	12.50	0.25	*Gentiana prostrata*	8	12.50	0.012
Planthanera dilitata	8	25.00	0.01	*Hedysarum alpinum*	8	50.00	0.62
Saxifraga aizoides	8	50.00	0.06	*Senecio lugens*	8	25.00	0.01
Thalictrum alpinum	8	75.00	0.14	*Tofieldia pusilla*	8	37.50	0.07
Woodsia ilvensis	8	12.50	0.01	*Equisetum arvense*	8	25.00	0.01
Equisetum scirpoides	8	25.00	0.01	*Selaginella selaginoides*	8	12.50	0.01
Parrya nudicaulis	8	25.00	0.06	*Parnassia palustris*	8	50.00	0.06
GRAMINOIDS							
Calamagrostis neglecta	8	37.50	0.31	*Carex eburnea*	8	25.00	0.06
Carex scirpoidea	8	87.50	4.93	*Elymus innovatus*	8	87.50	1.57
Festuca altaica	8	25.00	0.12				
BRYOPHYTES							
Brachythecium salebrosum	8	12.50	0.12	*Bryum sp.*	8	25.00	1.00
Dicranum groenlandicum	8	25.00	0.37	*Drepanocladus uncinatus*	8	62.50	2.01
Pleurozium schreberi	8	12.50	0.06	*Thuidium abietinum*	8	37.50	0.15
Rhytidium rugosum	8	50.00	1.50				

BORROW PIT B

SPECIES	N	FREQ	COV	SPECIES	N	FREQ	COV
TREES							
Larix laricina	9	11.11	0.01	*Picea glauca*	9	88.88	0.94
Picea mariana	9	11.11	0.055	*Populus balsamifera*	9	55.55	3.22
SHRUBS							
Alnus crispa	9	77.77	11.56	*Andromeda polifolia*	9	22.22	0.056
Arctostaphylos rubra	9	66.66	1.16	*Arctostaphylos uva-ursi*	9	55.55	0.44
Betula glandulosa	9	88.88	3.05	*Dryas drummondii*	9	22.22	0.012
Dryas integrifolia	9	100.00	16.78	*Empetrum nigrum*	9	22.22	0.01
Juniperus communis	9	77.77	0.09	*Ledum groenlandicum*	9	33.33	0.05
Linnaea borealis	9	22.22	0.05	*Potentilla fruticosa*	9	100.00	1.50
Rhododendron lapponicum	9	77.77	0.39	*Salix alaxensis*	9	88.88	9.77
Salix arbusculoides	9	77.77	1.22	*Salix brachycarpa*	9	11.11	0.11
Salix myrtillifolia	9	44.44	2.33	*Salix reticulata*	9	33.33	0.33
Vaccinium uliginosum	9	33.33	0.27	*Vaccinium vitis idaea*	9	22.22	0.01
HERBS							
Androsace chamaejasme	9	44.44	0.01	*Anemone parviflora*	9	88.88	0.11
Aster sibiricus	9	33.33	0.17	*Campanula aurita*	9	11.11	0.01
Castilleja raupii	9	11.11	0.01	*Cypripedium calceolus*	9	11.11	0.01
Cypripedium passerinum	9	11.11	0.11	*Epilobium latifolium*	9	55.55	0.50
Gentiana prostrata	9	11.11	0.011	*Planthanera dilitata*	9	77.77	0.19
Hedysarum alpinum	9	55.55	0.78	*Pedicularis labradorica*	9	11.11	0.01
Pinguicula vulgaris	9	11.11	0.05	*Pyrola asarifolia*	9	44.44	0.18
Pyrola secunda	9	44.44	0.88	*Saxifraga aizoides*	9	55.55	0.38
Saxifraga oppositifolia	9	11.11	0.01	*Senecio lugens*	9	55.55	0.09
Polygonum viviparum	9	44.44	0.01	*Thalictrum alpinum*	9	66.66	0.01
Tofieldia pusilla	9	77.77	0.44	*Equisetum arvense*	9	55.55	0.51
Equisetum scirpoides	9	55.55	0.11	*Selaginella selaginoides*	9	11.11	0.01
Parrya nudicaulis	9	44.44	0.12	*Parnassia palustris*	9	88.88	0.02
GRAMINOIDS							
Calamagrostis neglecta	9	44.44	0.11	*Carex membranacea*	9	11.11	0.22
Carex scirpoidea	9	77.77	1.83	*Carex vaginata*	9	22.22	0.056
Elymus innovatus	9	66.66	0.67	*Festuca altaica*	9	22.22	0.11
LICHENS							
Cladonia verticillata	9	11.11	0.01				
BRYOPHYTES							
Aulacomnium acuminatum	9	11.11	0.05	*Brachythecium salebrosum*	9	11.11	0.11
Bryum sp.	9	11.11	0.01	*Campylium stellatum*	9	11.11	0.11
Ditrichum flexicaule	9	11.11	0.11	*Drepanocladus revolvens*	9	11.11	0.22
Drepanocladus uncinatus	9	66.66	2.05	*Hylocomium splendens*	9	11.11	0.01
Pleurozium schreberi	9	11.11	0.01	*Thuidium abietinum*	9	44.44	0.83
Tortella sp.	9	11.11	0.11	*Rhytidium rugosum*	9	77.77	1.66

BORROW PIT F

SPECIES	N	FREQ	COV	SPECIES	N	FREQ	COV
TREES							
Larix laricina	7	14.28	0.57	*Picea glauca*	7	85.71	0.93
Picea mariana	7	57.14	0.50	*Populus balsamifera*	7	71.42	1.08
SHRUBS							
Andromeda polifolia	7	57.14	0.07	*Arctostaphylos rubra*	7	57.14	1.64
Arctostaphylos uva-ursi	7	42.85	1.85	*Betula glandulosa*	7	85.71	2.37
Dryas drummondii	7	71.42	0.50	*Dryas integrifolia*	7	100.00	6.35
Juniperus communis	7	14.28	0.01	*Juniperus horizontalis*	7	14.28	0.07
Linnaea borealis	7	14.28	0.14	*Potentilla fruticosa*	7	100.00	0.71
Rhododendron lapponicum	7	71.42	0.43	*Salix alaxensis*	7	100.00	3.93
Salix arbusculoides	7	57.14	0.21	*Salix bebbiana*	7	42.85	0.28
Salix glauca	7	28.57	0.14	*Salix myrtillifolia*	7	28.51	0.57
Shepherdia canadensis	7	57.14	0.11	*Vaccinium uliginosum*	7	14.28	0.07
HERBS							
Androsace chamaejasme	7	28.57	0.01	*Anemone parviflora*	7	71.42	0.02
Campanula aurita	7	14.28	0.01	*Centernnaria friesianna*	7	28.57	0.01
Planthanera dilitata	7	14.28	0.01	*Hedysarum alpinum*	7	42.85	0.21
Pyrola secunda	7	14.28	0.01	*Rumex arcticus*	7	14.28	0.01
Saxifraga aizoides	7	14.28	0.01	*Senecio atropupureus*	7	14.28	0.01
Stellaria longipes	7	57.14	0.10	*Thalictrum alpinum*	7	42.85	0.03
Tofieldia coccinea	7	14.28	0.01	*Woodsia ilvensis*	7	28.57	0.01
Equisetum arvense	7	14.28	0.28	*Selaginella selaginoides*	7	42.85	0.03
Parrya nudicaulis	7	28.57	0.01				
GRAMINOIDS							
Agropyron trachycaulum	7	14.28	0.07	*Carex microglochin*	7	57.14	0.35
Carex scirpoidea	7	42.85	0.28	*Carex vaginata*	7	42.85	0.64
Trisetum spicatum	7	14.28	0.01				
LICHENS							
Cetraria cucullata	7	14.28	0.01	*Cetraria islandica*	7	14.28	0.01
Cetraria nivalis	7	28.57	0.15	*Cladina mitis*	7	14.28	1.14
Cladonia stellaris	7	14.28	0.42	*Evernia mesomorpha*	7	14.28	0.01
Peltigera apthosa	7	14.28	0.01				
BRYOPHYTES							
Bryum sp.	7	14.28	0.01	*Ditrichum flexicaule*	7	14.28	0.01
Drepanocladus uncinatus	7	57.14	6.57	*Hylocomium splendens*	7	0.00	0.01
Hypnum bambergii	7	28.57	0.15	*Thuidium abietinum*	7	42.85	0.01

BLADED SLOPE D

SPECIES	N	FREQ	COV	SPECIES	N	FREQ	COV
TREES							
Larix laricina	8	25.00	0.06	*Picea glauca*	8	100.00	1.25
Populus balsamifera	8	87.50	4.00				
SHRUBS							
Alnus crispa	8	12.50	0.37	*Andromeda polifolia*	8	12.50	0.06
Arctostaphylos rubra	8	37.50	0.07	*Arctostaphylos uva-ursi*	8	75.00	1.20
Betula glandulosa	8	62.50	2.39	*Dryas drummondii*	8	75.00	7.75
Dryas integrifolia	8	75.00	8.62	*Juniperus communis*	8	37.50	0.08
Linnaea borealis	8	12.50	0.37	*Potentilla fruticosa*	8	62.50	0.27
Rhododendron lapponicum	8	12.50	0.01	*Salix alaxensis*	8	87.50	1.62
Salix arbusculoides	8	12.50	0.12	*Salix arctica*	8	12.50	0.01
Salix bebbiana	8	12.50	0.01	*Salix glauca*	8	25.00	0.12
Salix myrtillifolia	8	25.00	0.06	*Salix reticulata*	8	12.50	0.012
Salix scouleriana	8	12.50	0.01	*Shepherdia canadensis*	8	25.00	0.81
Vaccinium uliginosum	8	12.50	0.01				
HERBS							
Androsace chamaejasme	8	12.50	0.01	*Anemone parviflora*	8	75.00	0.19
Antennaria pulcherrima	8	12.50	0.06	*Cypripedium passerinum*	8	12.50	0.06
Epilobium angustifolium	8	12.50	0.12	*Epilobium latifolium*	8	25.00	0.06
Gentiana prostrata	8	25.00	0.02	*Goodyera repens*	8	12.50	0.01
Planthanera dilitata	8	37.50	0.02	*Habenaria oppositifolia*	8	12.50	0.37
Hedysarum alpinum	8	62.50	0.93	*Hedysarum boreale*	8	25.00	0.12
Oxytropis campestris	8	25.00	0.12	*Pedicularis labradorica*	8	12.50	0.01
Pyrola grandiflora	8	12.50	0.01	*Spiranthes romanzoffiana*	8	12.50	0.01
Stellaria longipes	8	12.50	0.01	*Tofieldia pusilla*	8	12.50	0.01
Equisetum palustre	8	12.50	0.01	*Equisetum scirpoides*	8	12.50	0.01
Parrya nudicaulis	8	75.00	0.33				
GRAMINOIDS							
Agropyron trachycaulum	8	12.50	0.01	*Carex scirpoidea*	8	50.00	0.06
Carex vaginata	8	12.50	0.25	*Elymus innovatus*	8	37.50	0.31
Festuca altaica	8	25.00	0.12	*Puccinellia deschampsiodes*	8	12.50	0.13
BRYOPHYTES							
Bryum sp.	8	12.50	0.012	*Ditrichum flexicaule*	8	25.00	0.12
Drepanocladus uncinatus	8	50.00	0.87	*Thuidium abietinum*	8	12.50	0.06
Rhytidium rugosum	8	12.50	0.01				

BLADED SLOPE G

SPECIES	N	FREQ	COV	SPECIES	N	FREQ	COV
TREES							
Picea glauca	5	20.00	0.01	*Picea mariana*	5	60.00	0.50
Populus balsamifera	5	20.00	0.80				
SHRUBS							
Alnus crispa	5	20.00	0.10	*Andromeda polifolia*	5	20.00	0.10
Arctostaphylos rubra	5	20.00	0.20	*Arctostaphylos uva-ursi*	5	40.00	0.22
Betula glandulosa	5	100.00	0.60	*Dryas drummondii*	5	80.00	2.20
Dryas integrifolia	5	100.00	8.00	*Empetrum nigrum*	5	20.00	0.00
Juniperus communis	5	60.00	0.32	*Linnaea borealis*	5	20.00	0.00
Potentilla fruticosa	5	100.00	0.50	*Rhododendron lapponicum*	5	60.00	0.30
Salix alaxensis	5	80.00	0.90	*Salix arbusculoides*	5	60.00	0.20
Salix bebbiana	5	60.00	0.01	*Salix glauca*	5	20.00	0.20
Salix myrtillifolia	5	40.00	0.20	*Shepherdia canadensis*	5	20.00	0.40
HERBS							
Androsace chamaejasme	5	40.00	0.01	*Anemone parviflora*	5	100.00	0.10
Campanula aurita	5	20.00	0.10	*Centernnaria friesianna*	5	20.00	0.10
Epilobium latifolium	5	20.00	0.01	*Galium boreale*	5	40.00	0.01
Planthanera dilitata	5	60.00	0.06	*Saxifraga aizoides*	5	20.00	0.01
Saxifraga oppositifolia	5	20.00	0.01	*Senecio lugens*	5	80.00	0.14
Stellaria longipes	5	40.00	0.02	*Thalictrum alpinum*	5	60.00	0.01
Tofieldia pusilla	5	20.00	0.10	*Woodsia ilvensis*	5	60.00	0.04
Zygadenus elegans	5	20.00	0.02	*Lycopodium selago*	5	20.00	0.02
Selaginella selaginoide	5	40.00	0.02	*Parrya nudicaulis*	5	20.00	0.01
Parnassia palustris	5	20.00	0.01				
GRAMINOIDS							
Carex microglochin	5	40.00	0.70	*Carex scirpoidea*	5	40.00	2.60
Carex vaginata	5	40.00	0.60	*Elymus innovatus*	5	80.00	0.12
Festuca altaica	5	20.00	0.10				
LICHENS							
Cetraria cucullata	5	20.00	0.01	*Cetraria islandica*	5	20.00	0.01
Cetraria nivalis	5	20.00	0.02	*Cladonia verticillata*	5	20.00	0.02
Dactylina arctica	5	20.00	0.10				
BRYOPHYTES							
Brachythecium salebrosum	5	20.00	0.10	*Ditrichum flexicaule*	5	20.00	0.02
Drepanocladus uncinatus	5	40.00	0.40	*Sphagnum fuscum*	5	20.00	0.02
Thuidium abietinum	5	40.00	0.01	*Rhytidium rugosum*	4	25.00	0.75

ROAD

SPECIES	N	FREQ	COV	SPECIES	N	FREQ	COV
TREES							
Picea glauca	35	94.28	0.97	*Populus balsamifera*	35	97.14	6.10
SHRUBS							
Alnus crispa	35	17.14	1.78	*Arctostaphylos rubra*	35	17.14	0.09
Arctostaphylos uva-ursi	35	22.85	0.13	*Betula glandulosa*	35	37.14	0.12
Cassiope tetragona	35	2.85	0.22	*Dryas drummondii*	35	94.28	42.86
Dryas integrifolia	35	65.71	4.53	*Empetrum nigrum*	35	8.57	0.06
Juniperus communis	35	14.28	0.01	*Ledum decumbens*	35	2.85	0.29
Ledum groenlandicum	35	2.85	0.02	*Linnaea borealis*	35	17.14	0.04
Oxycoccus microcarpus	35	2.85	0.01	*Potentilla fruticosa*	35	57.14	0.77
Rhododendron lapponicum	35	14.28	0.23	*Salix alaxensis*	35	60.00	3.96
Salix arbusculoides	35	40.00	0.22	*Salix arctica*	35	2.85	0.02
Salix arctophila	35	2.85	0.11	*Salix bebbiana*	35	8.57	0.01
Salix brachycarpa	35	45.71	1.72	*Salix glauca*	35	22.85	0.10
Salix myrtillifolia	35	17.14	0.05	*Salix reticu*[illegible]	35	11.42	0.03
Salix scouleriana	35	5.71	0.03	*Shepherdia canadensis*	35	31.42	0.23
Vaccinium uliginosum	35	5.71	0.01				
HERBS							
Androsace chamaejasme	35	8.57	0.01	*Anemone parviflora*	35	25.71	0.01
Antennaria pulcherrima	35	8.57	0.01	*Arnica alpina*	35	2.85	0.01
Aster sibiricus	35	14.28	0.01	*Boschniakia rossica*	35	2.85	0.01
Campanula aurita	35	2.85	0.01	*Castilleja caudata*	35	11.42	0.01
Castilleja raupii	35	11.42	0.01	*Cypripedium passerinum*	35	5.71	0.05
Erigeron hyssopifolius	35	2.85	0.01	*Epilobium angustifolium*	35	11.42	0.04
Epilobium latifolium	35	34.28	0.64	*Erigeron pumilus*	35	8.57	0.01
Gentiana prostrata	35	2.85	0.29	*Planthanera dilitata*	35	40.00	0.03
Hedysarum alpinum	35	8.57	0.86	*Hedysarum boreale*	35	8.57	0.08
Oxytropis campestris	35	2.85	0.28	*Pedicularis labradorica*	35	2.85	0.02
Planthanera hyperborea	35	5.71	0.01	*Pyrola asarifolia*	35	11.42	0.01
Pyrola secunda	35	11.42	0.01	*Saxifraga aizoides*	35	2.85	0.02
Senecio lugens	35	20.00	0.03	*Spiranthes romanzoffiana*	35	2.85	0.01
Thalictrum alpinum	35	8.57	0.01	*Zygadenus elegans*	35	11.42	0.08
Equisetum arvense	35	28.57	1.16	*Equisetum palustre*	35	8.57	0.08
Equisetum scirpoides	35	11.42	0.02	*Parrya nudicaulis*	35	11.42	0.01
Parnassia palustris	35	2.85	0.01				
GRAMINOIDS							
Arctagrostis latifolia	35	5.71	0.05	*Calamagrostis purpurascens*	35	2.85	0.11
Carex eburnea	35	2.85	0.01	*Carex microglochin*	35	28.57	0.13
Carex scirpoidea	35	17.14	0.07	*Carex vaginata*	35	14.28	0.07
Elymus innovatus	35	17.14	0.08	*Festuca altaica*	35	11.42	0.01
LICHENS							
Cetraria nivalis	35	2.85	0.02				
BRYOPHYTES							
Aulacomnium acuminatum	35	8.57	0.07	*Brachythecium salebrosum*	35	5.71	0.02

Bryum sp.	35	2.85	0.01	*Campylium stellatum*	35	17.14	0.08
Dicranum groenlandicum	35	8.57	0.03	*Ditrichum flexicaule*	35	34.28	0.10
Drepanocladus revolvens	35	2.85	0.01	*Drepanocladus uncinatus*	35	8.57	0.08
Hylocomium splendens	35	2.85	0.05	*Plagiomnium ellipticum*	35	5.71	0.11
Thuidium abietinum	35	17.14	0.13	*Tortella sp.*	35	2.85	0.01
Rhytidium rugosum	35	14.28	0.20				

TELEPHONE RIGHT-OF-WAY

SPECIES	N	FREQ	COV
TREES			
Larix laricina	25	20.00	0.96
Picea mariana	25	32.00	0.92
SHRUBS			
Andromeda polifolia	25	80.00	0.36
Arctostaphylos uva-ursi	25	12.00	0.20
Cassiope tetragona	25	4.00	0.40
Empetrum nigrum	25	80.00	0.94
Juniperus horizontalis	25	12.00	0.14
Ledum groenlandicum	25	84.00	2.80
Oxycoccus microcarpus	25	8.00	0.06
Rhododendron lapponicum	25	32.00	0.24
Salix arbusculoides	25	12.00	0.06
Salix bebbiana	25	28.00	0.54
Salix myrtillifolia	25	84.00	3.56
Salix scouleriana	25	4.00	0.02
Vaccinium uliginosum	25	96.00	2.16
Rosa acicularis	25	12.00	0.54
HERBS			
Orchis rotundifolia	25	8.00	0.02
Aster sibiricus	25	12.00	0.04
Epilobium angustifolium	25	4.00	0.04
Gentiana prostrata	25	16.00	0.01
Hedysarum alpinum	25	20.00	0.10
Papaver macounii	25	28.00	0.16
Pedicularis sudetica	25	12.00	0.02
Pinguicula vulgaris	25	4.00	0.01
Pyrola asarifolia	25	4.00	0.01
Rumex arcticus	25	12.00	0.01
Senecio lugens	25	4.00	0.04
Polygonum viviparum	25	40.00	0.09
Tofieldia pusilla	25	40.00	0.06
Equisetum arvense	25	44.00	0.70
Equisetum scirpoides	25	64.00	0.26
Parrya nudicaulis	25	8.00	0.08
GRAMINOIDS			
Agropyron violaceum	25	8.00	0.04
Carex lugens lenticula	25	20.00	0.26
Carex scirpoidea	25	80.00	2.22
Elymus innovatus	25	24.00	0.30
LICHENS			
Cetraria cvcullata	25	20.00	0.08
Cetraria nivalis	25	12.00	0.02
Cladina rangiferina	25	4.00	0.12
Cladonia coccifera	25	8.00	0.02

SPECIES	N	FREQ	COV
Picea glauca	25	76.00	3.18
Populus balsamifera	25	8.00	0.18
Arctostaphylos rubra	25	92.00	2.82
Betula glandulosa	25	96.00	6.96
Dryas integrifolia	25	72.00	3.04
Juniperus communis	25	44.00	0.30
Ledum decumbens	25	4.00	0.02
Linnaea borealis	25	64.00	0.48
Potentilla fruticosa	25	92.00	2.14
Salix alaxensis	25	28.00	3.96
Salix arctica	25	16.00	0.24
Salix glauca	25	16.00	0.28
Salix reticulata	25	28.00	0.30
Shepherdia canadensis	25	12.00	0.14
Vaccinium vitis-idaea	25	88.00	0.86
Androsace chamaejasme	25	4.00	0.02
Cypripedium passerinum	25	8.00	0.02
Erigeron subarctica	25	4.00	0.04
Planthanera dilitata	25	4.00	0.04
Moneses uniflora	25	4.00	0.01
Pedicularis labradorica	25	52.00	0.16
Pedicularis frigidus	25	8.00	0.04
Primula egaliksensis	25	4.00	0.04
Pyrola secunda	25	8.00	0.01
Saussurea angustifolia	25	56.00	0.56
Spiranthes romanzoffiana	25	4.00	0.01
Thalictrum alpinum	25	28.00	0.18
Zygadenus elegans	25	24.00	0.02
Equisetum palustre	25	4.00	0.04
Selaginella selaginoides	25	20.00	0.01
Parnassia palustris	25	48.00	0.05
Calamagrostis neglecta	25	4.00	0.02
Carex membranacea	25	12.00	0.06
Carex vaginata	25	72.00	2.60
Festuca altaica	25	84.00	2.24
Cetraria islandica	25	4.00	0.08
Cladina mitis	25	64.00	8.60
Cladonia amaurocraea	25	4.00	0.02
Cladonia gracilis	25	32.00	1.32

Cladonia verticillata	25	4.00	0.04	*Peltigera apthosa*	25	40.00	0.34
BRYOPHYTES							
Aulacomnium acuminatum	25	36.00	0.70	*Brachythecium salebrosum*	25	8.00	0.02
Bryum sp.	25	8.00	0.08	*Campylium stellatum*	25	24.00	1.16
Dicranum groenlandicum	25	28.00	1.04	*Ditrichum flexicaule*	25	28.00	0.82
Hylocomium splendens	25	68.00	24.30	*Hypnum bambergii*	25	20.00	1.12
Pleurozium schreberi	25	72.00	10.10	*Thuidium abietinum*	25	20.00	0.30
Rhytidium rugosum	25	84.00	9.06				

MINOR RIGHT-OF-WAY

SPECIES	N	FREQ	COV	SPECIES	N	FREQ	COV
TREES							
Larix laricina	20	40.0	0.60	*Picea glauca*	20	35.0	0.92
Picea mariana	20	90.0	0.73	*Populus balsamifera*	20	25.0	0.05
SHRUBS							
Alnus crispa	20	35.0	1.45	*Andromeda polifolia*	20	90.0	0.23
Arctostaphylos rubra	20	75.0	1.15	*Arctostaphylos uva-ursi*	20	45.0	0.55
Betula glandulosa	20	95.0	8.1	*Dryas integrifolia*	20	90.0	2.87
Empetrum nigrum	20	45.0	0.40	*Juniperus communis*	20	60.0	0.29
Ledum decumbens	20	5.0	0.10	*Ledum groenlandicum*	20	100	2.15
Linnaea borealis	20	65.0	0.97	*Potentilla fruticosa*	20	95.0	2.70
Rhododendron lapponicum	20	40.0	0.17	*Salix alaxensis*	20	45.0	0.55
Salix arbusculoides	20	40.0	0.62	*Salix arctica*	20	25.0	0.75
Salix bebbiana	20	5.0	0.025	*Salix brachycarpa*	20	40.0	0.45
Salix myrtillifolia	20	80.0	3.20	*Salix reticulata*	20	65.0	1.23
Shepherdia canadensis	20	10.0	0.03	*Vaccinium uliginosum*	20	95.0	1.12
Vaccinium vitis-idaea	20	95.0	0.60	*Rosa acicularis*	20	30.0	0.30
HERBS							
Androsace chamaejasme	20	10.0	0.01	*Anemone parviflora*	20	85.0	0.18
Antennaria pulcherrima	20	25.0	0.17	*Aster sibiricus*	20	25.0	0.05
Cypripedium calceolus	20	15.0	0.01	*Erigeron hyssopifolius*	20	5.0	0.01
Epilobium angustifolium	20	10.0	0.01	*Epilobium latifolium*	20	20.0	0.05
Erigeron subarctica	20	35.0	0.02	*Galium boreale*	20	10.0	0.03
Geocaulon lividum	20	25.0	0.03	*Gentiana prostrata*	20	15.0	0.01
Planthanera dilitata	20	40.0	0.05	*Hedysarum alpinum*	20	20.0	0.17
Papaver macounii	20	10.0	0.05	*Pedicularis labradorica*	20	55.0	0.15
Pedicularis frigidus	20	5.0	0.02	*Pinguicula vulgaris*	20	15.0	0.01
Saussurea angustifolia	20	40.0	0.22	*Saxifraga aizoides*	20	10.0	0.01
Saxifraga hieracifolia	20	5.0	0.5	*Senecio lugens*	20	40.0	0.05
Polygonum viviparum	20	55.0	0.04	*Stellaria longipes*	20	5.0	0.05
Thalictrum alpinum	20	70.0	0.34	*Tofieldia pusilla*	20	65.0	0.27
Zygadenus elegans	20	25.0	0.02	*Equisetum arvense*	20	45.0	3.20
Equisetum scirpoides	20	55.0	0.12	*Lycopodium selago*	20	5.0	0.03
Selaginella selaginoide	20	65.0	0.05	*Parrya nudicaulis*	20	20.0	0.01
Parnassia palustris	20	85.0	0.18				
GRAMINOIDS							
Agropyron violaceum	20	20.0	0.10	*Arctagrostis latifolia*	20	5.0	0.10
Calamagrostis purpurascens	20	25.0	0.23	*Carex eburnea*	20	5.0	0.05
Carex lugens lenticula	20	10.0	0.40	*Carex membranacea*	20	10.0	0.10
Carex scirpoidea	20	90.0	3.05	*Carex vaginata*	20	80.0	1.40
Elymus innovatus	20	50.0	0.27	*Festuca altaica*	20	80.0	1.65
Trisetum spicatum	20	15.0	0.10				
LICHENS							
Cetraria cucullata	20	25.0	0.18	*Cetraria islandica*	20	35.0	0.30
Cladina mitis	20	60.0	6.60	*Cladonia gracilis*	20	55.0	0.52
Cladonia pyxidata	20	5.0	0.05	*Evernia mesomorpha*	20	5.0	0.02

Peltigera apthosa	20	30.0	0.50				
BRYOPHYTES							
Aulacomnium acuminatum	20	20.0	0.60	*Bryum specie*	20	10.0	0.01
Campylium stellatum	20	10.0	0.22	*Dicranum groenlandicum*	20	40.0	0.80
Drepanocladus uncinatus	20	55.0	2.45	*Hylocomium splendens*	20	35.0	11.45
Hypnum bambergii	20	20.0	0.27	*Plagiomnium ellipticum*	20	5.0	
			0.05				
Pleurozium schreberi	20	75.0	10.1	*Thuidium abietinum*	20	65.0	1.15
Rhytidium rugosum	20	90.0	4.30	*Ptilidium ciliare*	20	5.0	0.10

MAJOR RIGHT-OF-WAY

SPECIES	N	FREQ	COV	SPECIES	N	FREQ	COV
TREES							
Picea glauca	15	73.33	0.33				
SHRUBS							
Alnus crispa	15	6.66	0.20	*Andromeda polifolia*	15	13.33	0.16
Arctostaphylos rubra	15	80.0	2.93	*Arctostaphylos uva-ursi*	15	73.33	0.97
Betula glandulosa	15	66.66	4.86	*Betula occidentalis*	15	6.66	0.13
Dryas drummondii	15	6.66	0.20	*Dryas integrifolia*	15	73.33	2.33
Empetrum nigrum	15	26.66	0.16	*Juniperus communis*	15	53.33	0.70
Ledum groenlandicum	15	86.66	2.33	*Linnaea borealis*	15	60.0	2.83
Potentilla fruticosa	15	80.0	1.3	*Salix alaxensis*	15	33.33	0.50
Salix arbusculoides	15	13.33	0.30	*Salix brachycarpa*	15	6.66	0.06
Salix glauca	15	13.33	0.46	*Salix myrtillifolia*	15	60.0	1.93
Salix reticulata	15	20.0	0.23	*Shepherdia canadensis*	15	20.0	0.20
Vaccinium uliginosum	15	80.0	5.06	*Vaccinium vitis-idaea*	15	60.0	0.60
Rosa acicularis	15	13.33	0.33				
HERBS							
Anemone parviflora	15	73.33	0.27	*Antennaria pulcherrima*	15	20.0	0.04
Aster sibiricus	15	33.33	0.16	*Castilleja caudata*	15	6.66	0.01
Cypripedium passerinum	15	6.66	0.03	*Erigeron hyssopifolius*	15	20.0	0.034
Geocaulon lividum	15	40.0	0.20	*Gentiana prostrata*	15	13.33	0.01
Goodyera repens	15	13.33	0.01	*Hedysarum alpinum*	15	66.66	0.73
Hedysarum boreale	15	40.0	1.06	*Lupinus arcticus*	15	26.66	0.30
Pedicularis labradorica	15	33.33	0.03	*Pedicularis sudetica*	15	6.66	0.01
Planthanera hyperborea	15	13.33	0.01	*Pyrola asarifolia*	15	40.0	0.20
Saussurea angustifolia	15	6.66	0.06	*Senecio lugens*	15	6.66	0.06
Polygonum viviparum	15	13.33	0.01	*Tofieldia pusilla*	15	33.33	0.06
Zygadenus elegans	15	6.66	0.06	*Equisetum arvense*	15	46.66	0.50
Equisetum palustre	15	20.0	0.16	*Equisetum scirpoides*	15	13.33	0.01
Selaginella selaginoides	15	26.66	0.01	*Parrya nudicaulis*	15	6.66	0.06
Parnassia palustris	15	60.0	0.10				
GRAMINOIDS							
Agropyron violaceum	15	6.66	0.03	*Carex eburnea*	15	6.66	0.06
Carex glacialis	15	66.66	1.0	*Carex membranacea*	15	20.0	9.2
Carex scirpoidea	15	60.0	1.60	*Carex vaginata*	15	20.0	0.10
Elymus innovatus	15	80.0	2.40	*Festuca altaica*	15	86.66	1.66
LICHENS							
Cetraria cucullata	15	20.0	0.01	*Cetraria islandica*	15	20.	0.13
Cetraria nivalis	15	13.3	0.06	*Cladina mitis*	15	33.3	4.20
Cladonia stellaris	15	13.3	1.53	*Cladonia coccifera*	15	13.3	0.01
Cladonia gracilis	15	40.0	0.56	*Peltigera apthosa*	15	6.66	0.06
BRYOPHYTES							
Brachythecium salebrosum	15	13.33	0.06	*Campylium stellatum*	15	6.66	0.06
Dicranum groenlandicum	15	26.66	0.20	*Ditrichum flexicaule*	15	40.0	0.93
Drepanocladus revolvens	15	6.66	0.53	*Drepanocladus uncinatus*	15	20.0	11.0

Hylocomium splendens	15	20	3.0	***Hypnum bambergii***	15	6.66	0.06
Plagiomnium ellipticum	15	6.66	0.03	***Pleurozium schreberi***	15	60.0	5.50
Thuidium abietinum	15	66.66	1.30	***Rhytidium rugosum***	15	53.33	0.73
Ptilidium ciliare	15	6.66	0.03				

STREAM BED

Populus balsamifera/ Dryas drummondii/ Epilobium latifolium/ Campylium stellatum Control

SPECIES	N	FREQ	COV	SPECIES	N	FREQ	COV
TREES							
Larix laricina	20	5.00	0.01	*Picea glauca*	20	55.00	0.31
Populus balsamifera	20	60.00	0.73				
SHRUBS							
Alnus crispa	20	15.00	0.07	*Arctostaphylos rubra*	20	15.00	0.05
Arctostaphylos uva-ursi	20	10.00	0.03	*Dryas drummondii*	20	100.00	35.30
Dryas integrifolia	20	5.00	0.02	*Empetrum nigrum*	20	10.00	0.07
Juniperus communis	20	5.00	0.01	*Linnaea borealis*	20	15.00	0.05
Potentilla fruticosa	20	15.00	0.03	*Salix alaxensis*	20	60.00	0.75
Salix arbusculoides	20	10.00	0.02	*Salix glauca*	20	5.00	0.01
Salix myrtillifolia	20	5.00	0.01	*Salix scouleriana*	20	5.00	0.05
Shepherdia canadensis	20	25.00	0.37	*Vaccinium vitis-idaea*	20	5.00	0.01
HERBS							
Anemone parviflora	20	15.00	0.02	*Aster sibiricus*	20	25.00	0.05
Cypripedium passerinum	20	10.00	0.01	*Epilobium latifolium*	20	55.00	1.15
Hedysarum alpinum	20	15.00	0.05	*Hedysarum boreale*	20	55.00	0.90
Lesquerella arctica	20	10.00	0.01	*Papaver macounii*	20	10.00	0.01
Planthanera hyperborea	20	5.00	0.01	*Pyrola asarifolia*	20	10.00	0.05
Pyrola secunda	20	10.00	0.02	*Equisetum arvense*	20	5.00	0.01
Equisetum palustre	20	30.00	0.02				
GRAMINOIDS							
Agropyron trachycaulum	20	35.00	0.05	*Calamagrostis purpurascens*	20	25.00	0.08
Carex eburnea	20	10.00	0.05	*Carex glacialis*	20	30.00	0.18
Carex scirpoidea	20	10.00	0.01	*Elymus innovatus*	20	25.00	0.40
Trisetum spicatum	20	85.00	0.89				
BRYOPHYTES							
Aulacomnium acuminatum	20	5.00	0.05	*Bryum sp.*	20	5.00	0.25
Campylium stellatum	20	15.00	0.52	*Ditrichum flexicaule*	20	5.00	0.25
Drepanocladus revolvens	20	10.00	0.12	*Hylocomium splendens*	20	5.00	0.01
Thuidium abietinum	20	10.00	0.03	*Tortella sp.*	20	5.00	0.02

APPENDIX VII: DISTURBANCE PLANT COMMUNITY SOILS

SOIL PROFILE: Borrow Pits

Gleyed Regosol

Horizon	Depth (cm)	
Cgk$_1$	0-15	Dark gray brown (2.5YR 4/2, moist) clay loam; moderate, medium sub-angular to weak, medium granular; plentiful fine and medium roots; excessively stony; gradual, smooth boundary; 10-20 cm thick; pH 7.9.
Cgk$_2$	15+	Very dark gray brown (10YR 3/2, moist) silt clay loam, moderate, medium sub-angular; very few medium roots; some gravel; pH 7.8.

SOIL PROFILE: Bladed Slope D

Eutric Brunisol

Horizon	Depth (cm)	
Bm	0-10	Grayish brown (2.5YR 5/2, moist) clay loam; moderate, medium angular to amorphous; plentiful medium to fine roots; excessively stony; gradual, smooth boundary; 8-11 cm thick; pH 8.0.
Ck	10-24	Dark gray brown (10YR 4/2, moist) sandy loam; moderate, medium sub-angular; very few medium roots; excessively stony; gradual, smooth boundary; 14 cm thick; pH 8.1.
Ckg	24+	Dark gray (10YR 4/1, moist) clay loam; strong, medium angular; very few roots; excessively stony; pH 8.1.

SOIL PROFILE: **Road**

Orthic Regosol

Horizon	Depth (cm)	
Ck_1	0-26	Dark gray brown (10YR 4/2, moist) sandy loam; weak fine granular to amorphous; plentiful medium to fine roots; excessively stony; gradual, smooth boundary; 16-34 cm thick; pH 7.9.
Ck_2	26+	Very dark gray brown (10YR 3/2, moist), dary gray (10YR 4/1, moist) loam; weak medium granular to amorphous; very few medium roots; excessively stony; pH 7.9.

SOIL PROFILE: **Road**

Cumulic Regosol

Horizon	Depth (cm)	
Ck_1	0-20	Brown (10YR 5/3, moist) dark gray brown (10YR 4/2, moist) sandy loam; weak fine granular to amorphous; plentiful medium to fine roots; excessively stony; clear smooth boundary; 15-25 cm thick; pH 7.6.
Ah	20-30	Black (10YR 2/1, moist) decomposed organic matter; humic and mesic; plentiful medium to fine roots; very stony; clear, smooth boundary; 5-25 cm thick; pH 6.8.
Ck_2	30+	Dark gray brown (10YR 4/2, moist) loam; amorphous; very vew medium to fine roots; excessively stony; pH 7.7.

SOIL PROFILE: Telephone Line Right-of-Way

Eutric Brunisol

Horizon	Depth (cm)	
L-H	28-0	Very dark brown (10YR 2/2, moist) organic matter; fibrous to humic, plentiful medium to fine roots; diffuse, irregular boundary; 22-33 cm thick; pH 6.5.
Bm_1	0-12	Very dark grayish brown (2.5YR 3/2, moist) sandy loam; weak, fine granular to amorphous; very vew medium roots; slightly stony; gradual, irregular boundary; 12 cm thick; pH 7.6.
Bm_2	12+	Dark brown (10YR 3/3, moist) loamy sand; weak, fine granular to amorphous; none; excessively stony; pH 7.8.

SOIL PROFILE: Telephone Line Right-of-Way

Orthic Gleysol

Horizon	Depth (cm)	
L-H	19-0	Very dark brown (10YR 2/2, moist) organic matter; fibrous to humic, plentiful medium to fine roots; gradual, wavy boundary; 1-40 cm thick; pH 6.3.
Bg	0-30	Dark gray brown (10YR 4/2, moist) sandy loam; common, medium distinct mottles very dark gray (10YR 3/1, moist); moderate, medium sug-angular to weak, fine granular; very few medium roots; slightly stony; gradu-smooth boundary; 14-50 cm thick; pH 7.4.
Cg	30+	Dark gray brown (10YR 4/2, moist) sandy loam; few, medium faint mottles, very dark gray brown (10YR 4/2, moist); moderate, medium subangular; very stony; pH 7.9.

SOIL PROFILE: Minor Right-of-Way

Orthic Gleysol

Horizon	Depth (cm)	
L-H	12-0	Dark reddish brown (5YR 2.5/2, moist) organic matter; litter to humic, plentiful medium to fine roots; clear, smooth boundary; 0-23 cm thick; pH 6.8.
Bg	0-34	Dark gray brown (10YR, moist) loam; few, fine, faint mottles very dark gray (10YR 3/1, moist); very few medium roots; moderate, medium sub-angular to weak fine granular; excessively stony; clear, smooth boundary; 17-50 cm thick; pH 7.2.
Ck	34+	Dark brown (10YR 4/3, moist) sandy loam; weak, medium granular; none; excessively stony; pH 7.5.

SOIL PROFILE: Major Right-of-Way

Cumulic Regosol

Horizon	Depth (cm)	
Ck_1	0-7	Grayish brown (10YR 5/2, moist) loam; amorphous; very few medium to fine roots; clear, smooth boundary; 7 cm thick; pH 8.0.
Ahk_1	7-10	Black (10YR 2/1, moist) decomposed organic matter; humic, plentiful medium to fine roots; gradual, wavy boundary; 2-5 cm thick; pH 7.4.
Bmk	10-21	Grayish brown (10YR 5/2, moist) loam; weak, fine granular to amorphous; plentiful medium to fine roots; gradual, wavy boundary; 8-15 cm thick; pH 7.8.
Ahk_2	21-22	Black (5YR 2/1, moist) decomposed organic matter; humic, none; clear, smooth boundary; 1 cm thick; ph 7.5.
Ck_2	22+	Dark brown (10YR 3/3, moist) loamy sand; amorphous; excessively stony; pH 8.1.

APPENDIX VIII: DECORANA AXIS SCORES OF CONTROL AND DISTURBANCE STANDS

DECORANA AXIS 1 AND 2 SCORES FOR THE 24 DISTURBANCE AND 21 CONTROL STANDS

MILEPOST 40, DODO VALLEY, N.W.T.

CONTROL	STAND	AXIS 1	AXIS 2
East Talus	A	116	75
	B	74	65
	C	73	71
	D	99	87
	E	116	62
	F	143	52
	G	89	64
West Terrace (Upper)	B	93	69
	C	26	43
	D	27	44
	E	30	0
	F	21	19
	G	69	47
West Terrace (Lower)	A	81	41
	B	16	24
	C	27	44
	D	0	29
	E	44	59
	F	53	143
Stream Bed	A	355	154
	B	389	170

DISTURBANCE	STAND	AXIS 1	AXIS 2
Borrow Pit	A	179	135
Borrow Pit	B	221	140
Borrow Pit	F	164	150
Bladed Slope	D	267	141
Bladed Slope	G	220	122
Road	A	342	158
	B	320	147
	C	375	165
	D	320	164
	E	377	166
	F	374	168
	G	347	155
Telephone R.O.W.	C	62	42
	D	23	42
	E	49	7
	F	7	45
	G	90	73
Minor R.O.W.	C	116	109
	D	67	66
	E	55	68
	F	32	54
Major R.O.W.	A	114	85
	B	62	73
	C	41	252

APPENDIX IX: SYSTEMATIC LIST OF PLANT TAXA OCCURRING IN THE STUDY AREA

CLADONIACEAE

Cladonia sp.

Cladonia alpestris (Opiz.) Brodo.

Cladonia amaurocraea (Floerke) Schaer.

Cladonia cenotea (Ach.) Schaer.

Cladonia coccifera (L.) Willd.

Cladonia gracilis (L.) Willd.

Cladonia mitis Sandst.

Cladonia multiformis Merr.

Cladonia phyllophora (Ehrh.) Hoffm.

Cladonia pyxidata (L.) Hoffm.

Cladonia rangiferina (L.) Web.

Cladonia verticillata (Hoffm.) Schaer.

PARMELIACEAE

Cetraria cucullata (Bell.) Arg.

Cetraria islandica (L.) Ach.

Cetraria nivalis (L.) Ach.

PELTIGERACEAE

Peltigera aphthosa (L.) Willd.

USNEACEAE

Dactylina arctica (Hook.) Nyl.

Evernia mesomorpha Nyl.

Non-Vascular Plants: Bryophytes

AMBLYSTEGIACEAE

Campylium stellatum (Hedw.) C.Jens.

Drepanocladus uncinatus (Hedw.) Warnt.

Drepanocladus revolvens (Sw.) Warnst.

AULACOMNIACEAE

Aulacomnium acuminatum (Lindb.& Arn.) Kindb.

BRACHYTHECIACEAE

Brachythecium salebrosum (Web.& Mohr.) B.S.G.

BRYACEAE

Bryum sp.

DICRANACEAE

Dicranum groenlandicum Brid.

DITRICHACEAE

Ditrichum flexicaule (Schwaegr.) Hampe.

ENTODONTACEAE

Pleurozium schreberi (Brid.) Mitt.

HYLOCOMNIACEAE

Hylocomnium splendens (Hedw.) B.S.G.

HYPNACEAE

Hypnum bambergii Schimp.

Ptilium crista-castrensis (Hedw.) De-Not.

MNIUMACEAE

Plagiomnium ellipticum (Brid.) Kop.

POTTIACEAE

Tortella sp.

PTILIDIACEAE

Ptilidium ciliare (L.) Hampe.

RHYTIDIACEAE

Rhytidium rugosum (hedw.) Lindb.

SPHAGNACEAE

Sphagnum fuscum (Schimp.) Klingr.

Sphagnum rubellum Wils.

THUIDIACEAE

Thuidium abientinum (Brid.) B.S.G.

Vascular Plants

BETULACEAE

Alnus crispa (Ait.) Pursh

Betula glandulosa Michx.

Betula occidentalis Hook.

CAMPANULACEAE

Campanula aurita Greene

CAPRIFOLIACEAE

Linnaea borealis (Forbes) Rehd.

CARYOPHYLLACEAE

Minuartia rossii (R.Br.) House

Stellaria edwardsii R.Br.

Stellaria longipes Goldie.

COMPOSITAE

Antennaria pulcherrima (Hook.) Greene.

Arnica alpina (L.) Olin.

Aster sibiricus L.

Chrysanthemum integrifolium Richards.

Erigeron hyssopifolius Michx.

Erigeron pumilis Nutt.

Saussurea angustifolia (Willd.) DC.

Senecio lugens Richards

CRUCIFERAE

Lesquerella arctica (Wormsk.) S.Wats.

Parrya nudicaulis (L.) Regel

CUPRESSACEAE

Juniperus communis L.

Juniperus horizontalis Moench.

CYPERACEAE

Carex aquatilis Wahlends.

Carex aurea Nutt.

Carex eburnea Boott.

Carex glacilis Mack.

Carex lugens Holm.

Carex membranacea Hook.

Carex microglochin Wahlenb.

Carex scirpoidea Michx.

Carex vaginata Tausch.

ELAEAGNACEAE

Sherpherdia canadensis Nutt.

EMPETRACEAE

Empetrum nigrum L.

EQUISETACEAE

Equisetum arvense L.

Equisetum palustre L.

Equisetum scirpoides Michx.

ERICACEAE

Andromeda polifolia L.

Arctostaphylos rubra (Rehd& Wilson) .

Arctostaphylos uva-ursi (L.) Spreng.

Cassiope tetragona (L.) D.Don.

Ledum decumbens (Ait.) Lodd.

Ledum groenlandicum Oeder

Oxycoccus microcarpus Turcz.

Rhododendron lapponicum (L.) Wahlenb.

Vaccinium uliginosum L.

Vaccinium vitis-idaea L.

GENTIANACEAE

Gentiana prostrata Haenke.

Lomatogonium rotatum (L.) Fries.

GRAMINEAE

Agropyron trachycaulum (Link.) Malte.

Agropyron violaceum (Hornem.) Lge.

Arctagrostis latifolia (R.Br.) Griseb.

Calamagrostis neglecta (Ehrh.) Gaertu.

Calamogrostis purpurascens R.Br.

Elymus innovatus Beal.

Festuca altaica Trin.

Puccinellia deschampoides Th. Sor

Trisetum spicatum (L.) Richter.

JUNCACEAE

Juncus balticus Willd.

LEGUMINOSAE

Hedysarum alpinum L.

Hedysarum boreale Nutt.

Lupinus arctica S.Wats.

Oxytropis campestris (L.) Dc.

LENTIBULARIACEAE

Pinguicula vulgaris L.

LILIACEAE

Tofieldia coccinea Richards.

Tofieldia pusilla (Michx.) Pers.

Zygadenus elegans Pursh.

LYCOPODIACEAE

Lycopodium selago L.

ONAGRACEAE

Epilobium angustifolium L.

Epilobium latifolium L.

ORCHIDACEAE

Amerorchis rotundifolia (Banks.) Hult.

Calypso bulbosa (L.) Oakes.

Cypripedium calceolus L.

Cypripedium passerinum Richards.

Gooderya repens (L.) Br.

Platanthera dilitata (Pursh) Lindl.

Platanthera hyperborea (L.) Lindl.

Spiranthes romanzoffiana Cham.

OROBANCHACEAE

Boschniakia rossica (Cham. & Schlecht.) Fedtsch.

PAPAVERACEAE

Papaver macounii Greene

PINACEAE

Larix laricina (DuRoi) K.Koch.

Picea glauca (moench.) Vors.

Picea mariana (Mill.) Bsp.

POLYGONACEAE

Polygonum viviparum L.

Rumex arcticus Trautv.

POLYPODIACEAE

Woodsia ilvensis (L.) R.Br.

PRIMULACEAE

Androsace chamaejasme Host.

Primula egaliksensis Wormsk.

PYROLACEAE

Moneses uniflora (L.) Gray.

Pyrola asarifolia Michx.

Pyrola chlorantha Swartz.

Pyrola grandiflora Radius.

Pyrola secunda L.

RANUNCULACEAE

Anemone parviflora Michx.

Thalictrum alpinum L.

ROSACEAE

Dryas drummondii Richards.

Dryas integrifolia M.Vahl.

Potentilla fruticosa L.

Rosa acicularis Lindle.

RUBIACEAE

Galium boreale L.

SALIACEAE

Populus balsamifera L.

Populus tremuloides Michx.

Salix alaxensis (Anderss.) Cov.

Salix arbusculoides Anderss.

Salix arctica Pall.

Salix arctophila Cockerell.

Salix bebbiana Sarg.

Salix brachycarpa Nutt.

Salix glauca L.

Salix myrtillifolia Anderss.

Salix reticulata L.

Salix scouleriana Barratt

SANTALACEAE

Geocaulon lividum (Richards) Fern.

SAXIFRAGACEAE

Parnassia palustris L.

Saxifraga aizoides L.

Saxifraga hieracifolia Waldst.& Kit.

Saxifraga hirculus L.

Saxifraga oppositifolia L.

SCROPHULARIACEAE

Castilleja caudata (Pennell) Rebr.

Castilleja raupii Pennell.

Pedicularis capitata Adams.

Pedicularis labradorica Wirsing.

Pedicularis sudetica Willd.

SELAGINELLACEAE

Selaginella selaginoides (L.) Link.